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THE ECE CULMINATING DESIGN EXPERIENCE: ANALYSIS OF ABET 2000 COMPLIANCE AT LEADING ACADEMIC INSTITUTIONS

A Thesis

Submitted to the Faculty

of

Purdue University

by

Nicholas John Schnettler

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science in Electrical and Computer Engineering

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This thesis is dedicated to my parents in gratitude for their endless love and support.

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ABSTRACT

Schnettler, Nicholas J. M.S.E.C.E.. Purdue University, May 2006. The ECE Culminating Design Experience: Analysis of ABET 2000 Compliance at Leading Academic Institutions. Major Professor   David G. Meyer.

The ABET (Accredidation Board for Engineering and Technology) Criteria for Accrediting Engineering Programs serve as a mechanism for creating consistency in American engineering programs. A significant element of these criteria is the design component, which specifies the need for a culminating design experience at the conclusion of the undergraduate degree. Given the generality of the ABET criteria, educational institutions are granted some level of autonomy in their actual implementation of the design component. While many institutions have exploited this freedom to a positive end, others appear to have diverged significantly from the intended spirit of the criteria. This work chronicles implementation of the culminating design experience component in electrical and computer engineering programs at top universities across the United States. A customized classification system is employed to demonstrate each university's effectiveness in implementing the design component and its associated outcomes. The results of these classifications are used to illustrate shortcomings in current implementations as well as propose possible revisions to the criteria to prevent future problems.

1. INTRODUCTION

The concept of standardizing undergraduate engineering programs stems from the desires of professional societies and industry to ensure a basic level of engineering proficiency in each engineering school graduate. Out of these desires was born the Accredidation Board for Engineering and Technology (ABET), a society which later became singly responsible for accrediting engineering and technology programs in the United States. In the year 2000, ABET released a radically revised set of criteria for accrediting engineering programs, henceforth referred to as ABET 2000. A response to prior criticisms concerning the lack of flexibility in the ABET criteria, ABET 2000 more generally outlined a list of outcomes to be realized by each program, thereby leaving specific implementation details to the individual institution. While this paradigm provided the freedom desired by prior critics, this thesis will argue that the same paradigm is allowing schools to be accredited that do not satisfactorily implement all aspects of the criteria.

For the purposes of this thesis, focus is restricted to Criteria 3 (c,f,g,h,k) and 4 of ABET 2000 (more specifically, the culminating design experience and its associated outcomes, often referred to as the "professional practice" outcomes). These areas embody the portion of the undergraduate experience wherein students employ practical application of engineering theory to realize useful designs. Prerequisites for each culminating design experience are also considered.

1.1 The Culminating Design Experience

Criterion 4 of [1] asserts, "Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier coursework and incorporating appropriate engineering standards and multiple realistic constraints." Often called a "Capstone Design Course" or "Senior Design Course," the culminating design experience in an engineering curriculum assists undergraduates as they transition from students of theory to practicing engineers.

It is in this forum that they begin to truly understand the relationships between different aspects of their chosen engineering disciplines, as well as understand the necessary balance between scientific theory and design practice. The authors of [7] characterize this accordingly: "…the major design experience needs to introduce students to the messiness of 'the real world,' a sense of ambiguity and uncertainty that is an essential component to humanities, social science, and management course content." Indeed, a key feature of the culminating design experience is a problem space that encompasses multiple engineering disciplines, ambiguity, unconstrained variables, and a direct impact on the world's social and economic fabric. While nearly every program surveyed for this thesis claims to fulfill Criterion 4 (and has recently been certified as doing so by ABET), this thesis will expose the reality of practical implementations.

1.2 The Professional Practice Component

Criterion 3 (c) of [1] specifies, "… an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability." This outcome is further supported by Criterion 3 (f,h,k). For this thesis, these elements are referred to as the "professional practice" component of a particular program. The key contribution that the professional practice outcomes make to the culminating design experience is context. Though most programs surveyed do culminate in some variation of a design project course, a significant number of the courses lack definitive and realistic constraints within which students must realize their designs. This thesis will argue that a culminating design experience does not satisfy the intent of Criterion 3 if it does not impose a definitive and realistic context for the design project.

1.3 The Technical Writing Component

Criterion 3 (g) of [1] further specifies, "… an ability to communicate effectively." Since engineering, by its very nature, is technical, this outcome is interpreted to be effective technical writing and communication. A culminating design experience must not focus solely on the engineering design constraints, but also on effectively conveying the design, its operation, and the fabrication process in both written and oral formats. For the purposes of a culminating design experience, technical writing skills enable students to describe their designs in written form. Most programs surveyed advertise their

culminating design experiences as “writing intensive” and require students to make regular presentations on their design progress, but provide little or no instruction on the actual practice of generating technical writing or technical presentations. This thesis will argue that only a focused course in technical communication prior to the culminating design experience truly satisfies the intent of this outcome.

1.4 The Data Set

In an effort to provide interesting contrasts as well as a representative sample, the top 25 engineering schools in both the doctorate-granting and non-doctorate-granting categories as listed in [2] were surveyed. This data set provides an adequate representation of schools that vary in enrollment as well as mission. The survey itself consisted of retrieving the undergraduate handbooks from each university and extracting from them the culminating design experience requirements and the pertinent prerequisites (specifically, technical writing and professional practice courses). Course descriptions were compiled and then each program was classified using the criteria described in Chapter 2. Survey and program classification results are outlined in Chapter 3 and detailed in Appendix A.

1.5 Related Work

National surveys of capstone design courses and industry practitioners represent a significant portion of related work. In [3], the authors report the results of a five year study: “…the efforts placed on how to teach engineering design courses have not addressed the more causal factor of what to teach … A lack of specificity and metrics regarding academic outcomes of senior design courses, and a divergence in learning constructs are observed.” Of particular value in this study is empirical evidence that the ABET 2000 Criteria 3 Program Outcomes lack sufficient specificity, an observation that thesis attempts to address. The ramifications of this lack of specificity are echoed in [8] where the authors describe a culminating design program that adequately addressed all ABET criteria, but was flagged for deficiency.

A second national survey, reported in [4], discusses assessment of ABET 2000 Criteria 3 and 4 in the context of a culminating design experience. Of particular pertinence to this thesis is a belief, supported by this survey, that ABET 2000 Criteria 3 (c,f,g,h,k) need to be assessed in the culminating design experience. Not only is this

belief supported, the results presented in [4] also indicate a general agreement that most institutions insufficiently assess the criteria in culminating design experience courses.

Though related work in this area sufficiently documents the existence of shortcomings in current academic programs and/or ABET 2000, causal relationships suggested by empirical data have yet to be presented.

1.6 Thesis Organization

This thesis is organized as follows. Chapter 2 describes the system used to classify the programs surveyed in this study. Chapter 3 presents the results of the survey and classification performed. Chapter 4 draws conclusions and outlines suggestions for improvement based on the trends demonstrated in Chapter 3. Finally, the epilogue applies the conclusions of Chapter 4 to the Electrical and Computer Engineering program at Purdue University.

2. CLASSIFICATIONS

To facilitate evaluation of a culminating design experience, it is necessary to first define a set of principles that characterize that experience. Given the generality of ABET 2000, it is easy to understand the existence of variations in practical implementations. With these notions in mind, the classifications developed for this study evaluate programs based on their framework, content, and length. Framework defines the course sequencing used to realize a design experience (here designated as Capstone or Capstone Certified), content defines the particular concepts addressed within that framework (professional practice and technical writing), and length indicates the number of semesters needed to complete the experience.

2.1 Classification of the Culminating Design Experience Framework

The initial list of characteristics to quantify did not initially include the *type* of design experience, primarily because the author assumed that all programs would have a culminating design experience, and that that experience would conform to a general framework. Perhaps one of the most surprising revelations, no doubt due to the flexibility of ABET 2000, was the emergence of not one, but two distinct frameworks, as well as one program with no culminating design experience at all. Though both models involve a design project, they vary drastically in how that design project is selected and implemented.

2.1.1 The Capstone Classification

The first variation on the culminating design experience framework, bearing the designation “Capstone”, is what the author originally hypothesized to be the only framework. A Capstone culminating design experience is one in which every student follows the same progression of courses but is potentially allowed to select the type of project they wish to design. A common implementation of this framework might take

place over two semesters. In the first semester, students learn about professional practice issues as well as the steps to generate a sound design proposal. In the subsequent semester, students implement the design proposed and document the process, as well as their results. During the semester in which the design project actually takes place, students are typically constrained to a singular development platform, such as embedded design using microcontrollers.

2.1.2 The Capstone Certified Classification

The second variation on the culminating design experience, bearing the designation “Capstone Certified”, represents the framework discovered during the data collection phase. A Capstone Certified culminating design experience is one in which students are presented with a selection of courses that have been deemed worthy of satisfying the culminating design requirement. Many permutations of this framework appear in the data set, the most frequent of which is a one-semester program where students select a culminating design course in an area of electrical or computer engineering that interests them (e.g. controls, computer architecture, signal processing, wireless communications, etc.).

2.1.3 Unclassified Programs

Fortunately, all but one of the programs surveyed fell into one of the two aforementioned categories. For the single outlier, a designation of “unclassified” seemed most appropriate. This classification is reserved for programs that appear to definitively violate Criteria 4 by failing to require any conventional form of culminating design experience.

2.2 Classification of the Professional Practice Content Component

The first of the two content components, professional practice, refers to the context applied to a given design experience. With respect to ABET 2000, design experience context is defined by Criteria 3 (c,f,h,k). Survey results in [3] and [4] suggest that this is not only an appropriate aspect of a culminating design experience, but a necessary one. Because practicing engineers must consider realistic constraints when designing, it is logical that a culminating design experience emulate that “sense of

reality" in any way possible. To achieve a satisfactory mark for the professional practice content component, a program must require students to design within a realistic set of constraints (such as those outlined in Criterion 3 (c)).

2.3 Classification of the Technical Writing Content Component

The second content component, technical writing, addresses the student's ability to communicate technical material in both oral and written forms. Though significant previous work has focused on the communication requirements imposed by ABET 2000 and their relationship to the culminating design experience [5-6], actual technical communication skills are often considered *a priori* knowledge for a capstone design course [3]. While nearly all of the culminating design experiences surveyed are classified in course catalog descriptions as "writing intensive" and/or heavily focused on technical communication, a rare few actually instruct students in technical communication and less than half require technical writing as a prerequisite. Given the already saturated schedules experienced in design courses, it seems implausible to impose any further expectations on the design course itself. Even if the design course briefly covered technical communication topics, significant opportunities to practice those lessons would be difficult to balance with all other design course requirements. For these reasons, the most effective implementation of the technical writing component is a dedicated course in technical writing that is a prerequisite to the culminating design experience. As such, a program must have a prerequisite dedicated technical writing course to receive a satisfactory mark for the technical writing content component.

2.4 Program Length

Though the length of a given design experience may seem irrelevant, the author chose to track this aspect of each program based on the hypothesis that a relationship may exist between program length and satisfactory implementation of the ABET 2000 accreditation requirements. It is conceivable that all objectives of the culminating design experience may be achieved in a single semester, however a longer program affords students the ability to absorb the gravity of their design experience. Findings published in [3] suggest that a meaningful design experience should afford students enough time to complete multiple iterations of their designs as needed as well as make connections between the tools they use in design courses and their applications in industry.

Accommodation of requirements such as these seems intractable in a single semester. The authors of [9] and [10] compare many culminating design formats where the length of the program (and number of projects) is varied, and conclude that a multiple semester approach is the most effective. With these considerations in mind, the length of each program surveyed was tracked in conjunction with the classification process.

3. DATA AND RESULTS

The data analyzed in this study is comprised of the top 25 doctorate granting and top 25 non-doctorate granting engineering universities, as ranked in [2]. The degree requirements for undergraduate students enrolled in the electrical and computer engineering program at each candidate university were reviewed, with particular focus given to the requirements for a culminating design experience, professional practice, and technical writing. Based on this review, a summary of each program was generated. Following collection of all survey data, the classification system outlined in Chapter 2 was applied to each program. Summaries of each program surveyed, along with detailed explanations for each classification assigned, can be found in Appendix A.

A key feature of this data set is the natural cross-sections that exist. The primary cross-section, doctorate-granting and non-doctorate-granting institutions, provides an interesting comparison between large and small schools: the doctorate-granting institutions tend to be large schools with greater variations in curricular offerings, while the non-doctorate-granting institutions tend to be smaller schools with more focused programs. Additionally, there tends to be a significant difference in stated missions. Doctorate-granting schools tend to offer both theoretical and practical culminating design experiences, while the non-doctorate-granting schools tend to offer only the latter. These differences demonstrate a significant variation in the number of satisfactory ABET 2000 implementations.

Another cross-section of interest is a bit more causal in nature. The existence of the Capstone and Capstone Certified comparison directly stems from the inherent flexibility of the larger, doctorate-granting institutions. While the Capstone programs offer a single sequence of courses that constitute the culminating design experience, the Capstone Certified programs, hosted at institutions with larger faculties and more areas of specialization, offer a variety of culminating design experiences. This difference in program structures also demonstrates large variations in implementations of ABET 2000 criteria.

3.1 Doctorate- and non-Doctorate-Granting Institutions

Table 3.1.1: Classifications of Doctorate-Granting Programs

School	Classification
Massachusetts Institute of Technology	Capstone
Stanford University	Certified
University of California – Berkeley	Certified
California Institute of Technology	Capstone
University of Illinois - Urbana-Champaign	Capstone
Georgia Institute of Technology	Certified
University of Michigan - Ann Arbor	Certified
Carnegie Mellon University	Certified
Purdue University - West Lafayette	Capstone
Cornell University	Certified
University of Texas – Austin	Capstone
Princeton University	Certified
Johns Hopkins University	Certified
Northwestern University	Certified
University of Wisconsin – Madison	Certified
Penn State University - University Park	Capstone
Rensselaer Polytechnic Institute	Certified
Texas A&M	Capstone
Rice University	Certified
University of Minnesota – Twin Cities	Capstone
Virginia Institute of Technology	Certified
Duke University	Certified
University of California - Los Angeles	Unclassified
University of California - San Diego	Certified
University of Maryland - College Park	Certified
University of Southern California	Certified
University of Washington	Certified

Doctorate-granting programs distinguish themselves by two characteristics: (1) high levels of variability in program structures and (2) relatively low levels of ABET 2000 compliance. A simple analysis of the classifications listed in Table 3.1.1 reveals a balance of both Capstone and Capstone Certified program structures. While this result may seem favorable to the casual observer, the diversity illustrated is strongly correlated to a lack of ABET compliance. Within the doctorate-granting cross-section, only 15% of the programs surveyed were found to be in full compliance of ABET 2000. Even more egregious is the fact that 51% of the doctorate granting programs fail to satisfy both the

professional practice and technical writing components. A more detailed illustration of these results appears in Figure 3.1.1.

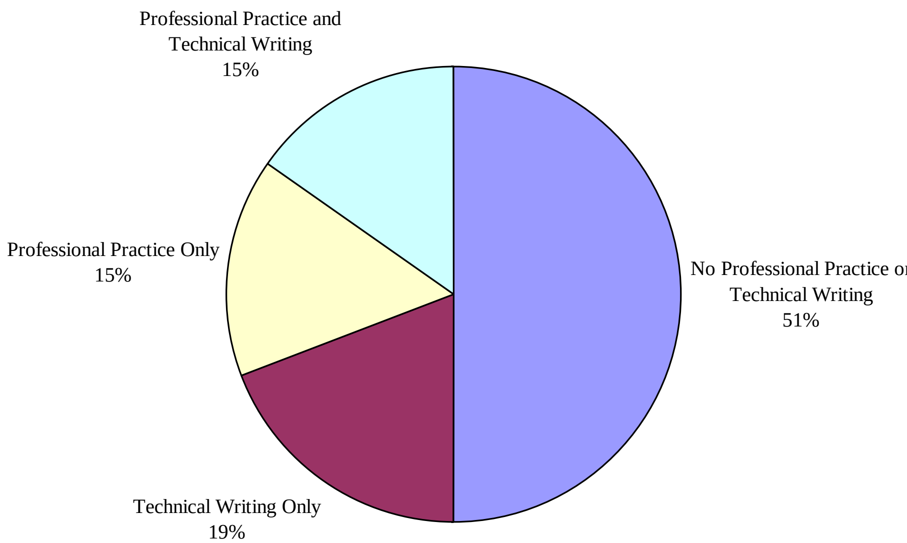

Figure 3.1.1: Doctorate-Granting Program Component Classifications

Non-doctorate-granting programs demonstrate an opposite trend in terms of distinguishing characteristics: the program structures are more consistent, as is ABET compliance. All non-doctorate-granting programs surveyed earned a Capstone classification (see Table 3.1.2 for a listing of the non-doctorate-granting programs). Non-doctorate-programs also received higher ratings in the component classifications, with 40% having both components satisfactorily implemented and a mere 8% having neither. A summary of the component classification results for the non-doctorate-granting programs appears in Figure 3.1.2.

Table 3.1.2: Classifications of Non-Doctorate-Granting Programs

School	**Classification**
Rose-Hulman Institute of Technology	Capstone
Harvey Mudd College	Capstone
Cooper Union	Capstone
Cal Poly - San Luis Obispo	Capstone
United States Military Academy	Capstone
United States Naval Academy	Capstone
United States Air Force Academy	Capstone
Bucknell University	Capstone
Kettering University	Capstone
Embry Riddle Aeronautical University	Capstone
Milwaukee School of Engineering	Capstone
Villanova University	Capstone
California State Polytechnic University - Pamona	Capstone
Lafayette College	Capstone
Loyola Marymount University	Capstone
San Jose State University	Capstone
Santa Clara University	Capstone
United States Coast Guard Academy	Capstone
Baylor University	Capstone
Gonzaga University	Capstone
Union College	Capstone
University of Colorado – Colorado Springs	Capstone
University of Michigan – Dearborn	Capstone
Valparaiso University	Capstone
Virginia Military Institute	Capstone

The stark contrast in component classifications between the doctorate- and non-doctorate-granting programs is most clearly explained by the variable program structure commonly found in doctorate granting programs. The doctorate granting institutions tend to employ a larger, more technically diverse faculty capable of supporting culminating design experiences in a variety of areas within electrical and computer engineering. While this assortment of options may be attractive to students, from an academic standards perspective, it complicates any efforts to maintain a semblance of uniformity in the satisfaction of Criteria 3 and 4. The following section further illustrates this point.

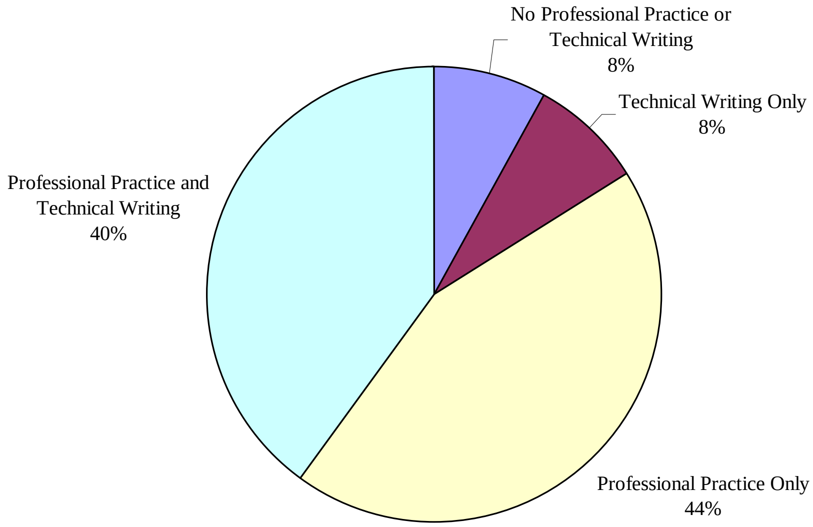

Figure 3.1.2: Non-Doctorate-Granting Program Component Classifications

3.2 Capstone and Capstone Certified Programs

The Capstone and Capstone Certified cross-section further demonstrates the strong influence program structure has on the satisfaction of ABET 2000. Figures 3.2.1 and 3.2.2 illustrate the component classifications based on program framework classifications. From these plots, it is clear that the Capstone program structure tends to yield a more consistently satisfactory program. Only 18% of the Capstone programs surveyed failed to satisfy both component classifications compared to 50% of the Capstone Certified programs.

Figure 3.2.1: Capstone Programs

When the component classifications were established for this study, they were ranked based on their relative importance. While it should be intuitively obvious why satisfaction of both components receives the highest importance and satisfaction of neither receives the lowest, the ordering of the two intermediate classifications deserves some explanation. As was previously stated in Chapter 2, the professional practice component provides not only an important context for the culminating design experience, but also helps determine a realistic set of constraints for the design. Though technical writing skills are an important prerequisite skill for maximizing the meaning garnered from the design experience, it can be easily argued that insufficient focus on the technical writing component only marginally affects the overall experience. A lack of focus on the professional practice component, however, can result in a significantly less meaningful experience. For this reason, satisfaction of the professional practice component is given a higher importance.

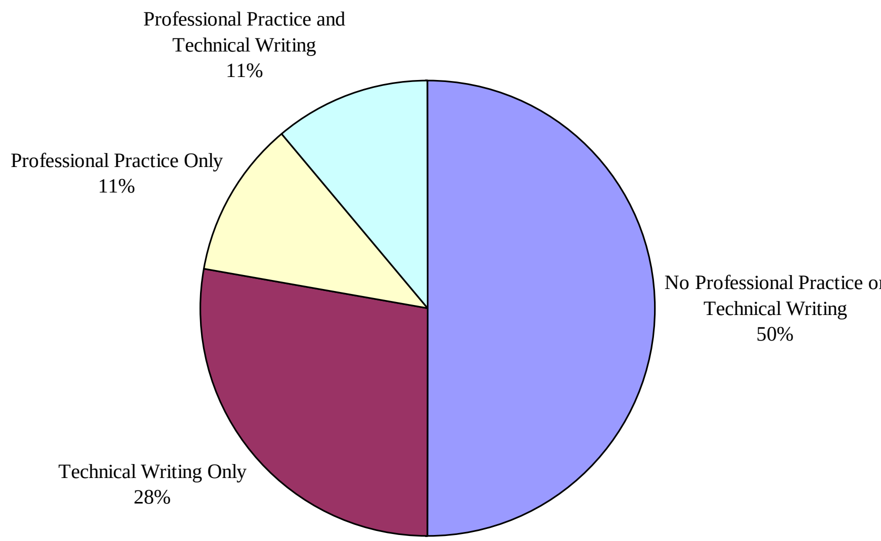

Figure 3.2.2: Capstone Certified Programs

With these observations in mind, a more dramatic comparison of Capstone and Capstone Certified programs emerges. Using a satisfaction threshold of “Professional Practice Only”, more than 75% of the Capstone programs receive a satisfactory rating in the component classification while over 75% of the Capstone Certified programs receive an unsatisfactory rating. Clearly, this illustrates that the Capstone Certified program format, at least in its current form, is inadequate for satisfying ABET 2000.

A fairly simple explanation for the shortcomings of the Capstone Certified program structure lies in the descriptions of Capstone and Capstone Certified courses. While a majority of the Capstone courses surveyed are some variant on a microcontroller-based embedded design course, there is a plethora of courses used in Capstone Certified programs ranging from Computer Architecture and Prototyping to Image Processing. Though it can be argued that most of the Capstone Certified courses constitute significant design experiences, careful review of their course descriptions reveals that they often fail to enforce any realistic constraints for the design. Courses such as computer architecture and image processing at the undergraduate level typically require a great deal of theoretical course content in parallel with completing the design

projects. Conversely, a course in microcontroller-based design requires little additional theory, thereby granting students the freedom to focus on the actual design process and the constraints involved (assuming that course is based on a prerequisite course, as are a majority of the programs surveyed in this category).

3.3 Reflections on Program Length

As stated in Chapter 2, the length of each program surveyed was tracked based on a hypothesized relationship between program length and satisfaction of ABET 2000. Using the same satisfaction threshold established in 3.2, it is clear that 82% of the programs receiving a satisfactory rating in the component classifications take more than a single semester to complete. In contrast, over 50% of the programs receiving an unsatisfactory rating in the component classifications are only a single semester in length. A summary of this relationship is reported in Figure 3.3.1.

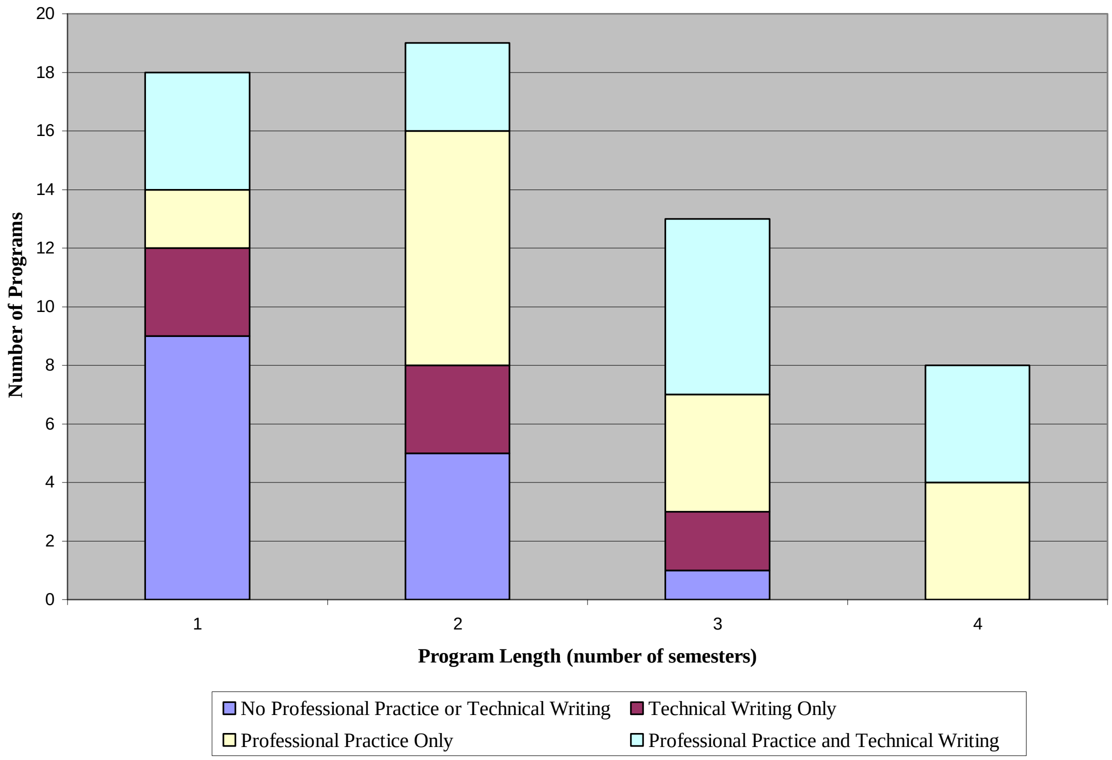

Figure 3.3.1: Length of Program (Component Classification comparison)

Another interesting trend emerges when considering program length in conjunction with the program framework. Figure 3.3.2 indicates that over 75% of the Capstone programs are more than a semester in length, while more than 50% of the Capstone Certified programs are only one semester long. When combined with findings reported in 3.2, a potential explanation for the lack of ABET 2000 satisfaction in Capstone Certified courses becomes apparent.

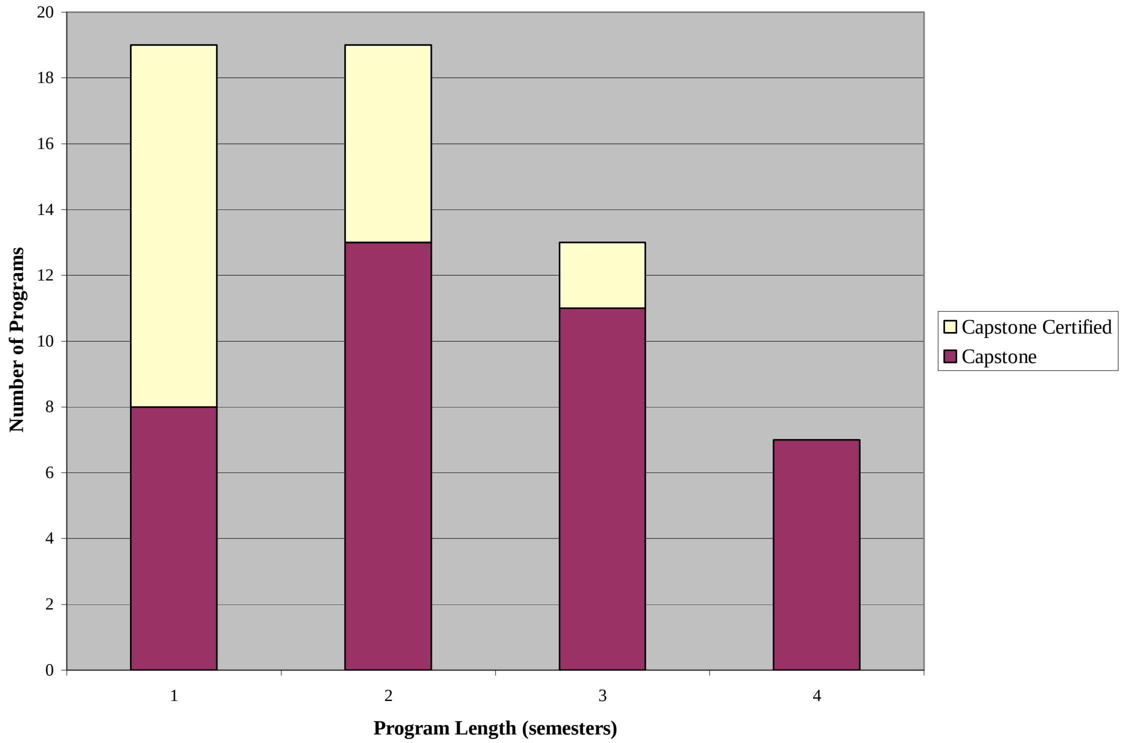

Figure 3.3.2: Length of Culminating Design Experience (Capstone comparison)

4. CONCLUSIONS AND RECOMMENDATIONS

The goal of this thesis was to investigate causality for shortcomings in culminating design experiences and ABET 2000. A survey of undergraduate electrical and computer engineering programs at the top 25 doctorate-granting and non-doctorate-granting institutions in the United States was conducted, and the results of this study strongly suggest relationships between satisfaction of ABET 2000 and particular program implementations. Indeed, the framework, content, and length of a culminating design experience play key roles in the success or failure of a particular program.

4.1 Framework

When considering design program framework, it is clear that the Capstone framework, perhaps due to its regimented nature, maintains greater consistency than does the Capstone Certified framework. Intuitively, this result makes perfect sense: if all students are required to take the same sequence of courses, it is easier to ensure that they have a regular and consistent experience. Deficiencies in the Capstone Certified framework exist in two major areas: course selection criteria and regularity of content (Section 4.2 addresses the latter).

As previously alluded, a vast majority of the Capstone Certified programs surveyed consist of a collection of courses covering many areas of electrical and computer engineering design. Often the design experiences in these programs rely heavily on theory developed within the culminating design experience. This reliance not only consumes significant course time to teach the theory, but also severely limits the scope and size of a potential project. In contrast, many of the culminating design courses used in the Capstone programs rely on prerequisite courses to instill the required theory.

A suggestion to improve consistency, and thereby satisfaction of ABET 2000, is to refine the criteria with which culminating design courses are certified. Requirements such as limited theoretical development within the culminating design course should be

enforced so that the focus remains primarily on the design experience, not the knowledge needed to understand what is being designed.

4.2 Content

The content of a culminating design experience, specifically technical communication and professional practice which bear direct pertinence to the design experience itself, also contributed significantly to satisfaction of ABET 2000. Trends in this area indicate that most programs consider technical communication skills prerequisite knowledge for a design experience, but few actually include a course in technical communication as part of the degree requirements. Survey results from prior work in this area strongly suggest that industry practitioners are dissatisfied with the lack of these skills demonstrated by current graduates. Furthermore, as more culminating design courses require significant quantities of writing and presentations concerning evolution of the design project, it is clear that adjustments in current program implementations must adapt to facilitate actually teaching these skills.

Attention must also be paid to the professional practice aspect of a design experience. A second area where the Capstone Certified framework commonly suffered was consistency of the professional practice material being taught. Within a particular program, it was commonly observed that some courses dedicated multiple months to the discussion of professional practice while others failed to even mention it. Across both frameworks, it was also clear that a consistent understanding of professional practice issues does not exist even though ABET 2000 clearly defines them in Criterion 3. Many programs that received unsatisfactory marks in the professional practice component classification did so because they neglected to cover *all* of the aspects of professional practice, possibly due to this perceived lack of understanding.

To improve the consistency, as well as adequacy of coverage, of the professional practice component, all programs should cover the material in a dedicated course that is a prerequisite to the culminating design experience. Such a course would ideally require students to write a design proposal for the culminating design experience that considers practical design constraints, patent liabilities, reliability and safety analyses, and socio-economic impacts of the design. This benefits the Capstone Certified framework in particular because a prerequisite course ensures that all students, regardless of the design experience they choose, receive the same instruction in this area. A dedicated prerequisite course in technical communication should also be considered, thereby giving

students sufficient preparation for a culminating design experience that is writing and presentation intensive.

4.3 Length

Empirical data strongly suggests that programs of at least two semesters in length have a higher probability of satisfying ABET 2000. Given suggestions in the preceding sections, it is conceivable that adequate culminating design experiences need multiple semesters just to ensure proper coverage of all material. A multiple semester experience additionally allows for an iterative design process, a concept often overlooked in single semester programs.

An ideal program format would have a prerequisite list that includes an intensive course in technical communication. In the first semester, students would attend lectures that address professional practice issues, all of which culminate in the production of a design proposal to be implemented in the following semester (to pass the course, the proposal would have to be approved by a faculty member or committee). In the following semester, students would implement the proposed design, preparing regular progress reports and presentations that chronicle evolution of the design.

4.4 ABET 2000

This thesis has documented the realities in many practical implementations of the ABET 2000 Criteria. The generality of the criteria bear some of the blame for shortcomings, and as such, the author suggests the following revisions:

(1) While the framework of a culminating design experience need not be dictated, specific guidelines or expectations concerning how a design experience should be conducted need to be stated. These guidelines would include criteria for selecting what styles of courses are appropriate culminating design experiences (pertinent specifically to programs employing the Capstone Certified framework).

(2) Though not the specific focus of this work, survey results indicate that a “Senior Thesis” was commonly used to satisfy the culminating design experience, especially at doctorate-granting institutions. The appropriateness of this practice needs to be addressed. It is the author’s conclusion that a senior thesis does not constitute an adequate

culminating design experience, as it is too theoretical in nature and deprives students from experiencing a practical design process.

(3) Criterion 3 (g) needs to be refined to specify technical communication. As this thesis has argued, only a focused course in technical communication should satisfy this criterion.

Given all these modifications, as well as the perceived importance of the culminating design experience, it seems reasonable that an entire criterion within the ABET Criteria be dedicated to its evaluation.

EPILOGUE: ECE CAPSTONE DESIGN AT PURDUE UNIVERSITY

As an undergraduate alumnus of the School of Electrical and Computer Engineering at Purdue University, as well as a Teaching Assistant for one of the culminating design experiences at said school, it seems appropriate to reflect upon the meaning of this thesis at Purdue. Recognizing Purdue's dedication to excellence in engineering, and its desire to remain competitive with peer institutions, the ECE Undergraduate Curriculum Committee should consider revising the culminating design program requirements in the following ways:

(1) A professional practice course should be implemented to standardize the design-related content being taught and required as a prerequisite to ECE 402, 477, 490, and any future courses certified as senior design. Currently, these courses do not uniformly cover the same quantities or aspects of this content component.

(2) The current undergraduate program only requires students to take an expository writing course and an introductory public speaking course. Although technical reports and presentations are required in all three design courses, none of these courses actually teaches technical communication skills. A requirement should be imposed requiring all students to take a course in technical writing and communication prior to beginning the culminating design experience. This will ensure that students are adequately prepared to deliver the required reports and presentations.

(3) Consideration should be given to include ECE 461 "Software Engineering" an option for the culminating design requirement. This course covers many current professional practice issues specific to software development, including process models and project management techniques, as well as a significant design project that requires development of a large scale software project. A distinct shortcoming of Purdue ECE program as compared to other peer

institutions is its heavy hardware focus. This is a particular disadvantage to those students pursuing a degree in computer engineering. A more robust program would require computer engineering students to take ECE 461 *in addition to* ECE 402/477/490, or at least allow ECE 461 to count for culminating design experience credit.

(4) Consideration needs to be made to standardize the content and evaluation of the senior design course offered. Current assessment practice in ECE 402/477/490 is not uniform. A possible solution is to establish a baseline set of deliverables and a standard set of assessment strategies for all courses. Of utmost importance is to formulate *quantitative* methods that uniformly assess work in the senior design courses. Prior work in this area is reported in [11].

Application of these recommendations should not only ease future ABET accreditation visits, but also improve the overall quality of the graduates produced by the School of Electrical and Computer Engineering at Purdue.

LIST OF REFERENCES

LIST OF REFERENCES

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APPENENDICES

A. DATA POOL

What follows is a listing of all data used for this study.

School Name	Massachusetts Institute of Technology
Data Source	"A Brief Guide to MIT's EECS Degree Programs" (http://www.eecs.mit.edu/ug/brief-guide.html)
Classification	Capstone
Program Description	Students are required to take both of the listed courses. There appears to be no course in the curriculum that addresses professional practice or technical writing issues.
Course Descriptions	**6.UAT: Preparation for Undergraduate Advanced Project** Learn about different aspects of effective technical oral presentations by being exposed to different workplace communication skills. As preparation for the advanced undergraduate project (UAP), students develop research topics, identify a research supervisor, and prepare a short research proposal for written and oral presentation. **6.UAP: Undergraduate Advanced Project** Research project for those students completing the SB degree, to be arranged by the student and an appropriate MIT faculty member. Students who register for this subject must consult the Department Undergraduate Office. Students engage in extensive written communications exercises.

School Name	Stanford University
Data Source	"2005-06 Electrical Engineering Undergraduate Handbook" (http://www-ee.stanford.edu/draft05ughb.pdf) "EE Course Web Pages" (http://www-ee.stanford.edu/class_directory.php)
Classification	Capstone Certified
Program Description	Students are required to take ENGR 102E, EE 100, and at least one of the listed elective design courses.
Course Descriptions	**ENGR 102E: Technical/Professional Writing** **EE 100: The Electrical Engineering Profession** Lectures and discussions on topics of importance to the electrical engineering professional. Continuing education, professional societies, intellectual property and patents, ethics, entrepreneurial engineering, and engineering management. **EE 133: Analog Communications Design Laboratory** Design and testing of analog communications circuits, such as: • Amplitude modulation (AM) using discrete multiplier circuits and fully integrated implementations. • Frequency Modulation (FM) based on discrete and integrated modulator circuits such as voltage-controlled oscillators (VCOs). • Phase-Lock Loop (PLL) techniques, characterization of key parameters and their applications, e.g., in modems. Lectures on the practical aspects of circuit implementations. Labs involve the systematic building and characterization of AM, FM, and PLL circuits and subsystems. **EE 144: Wireless Electromagnetic Design Laboratory** Lecture, lab, and design project. Hands-on experiments and projects with transmission lines, antennas and propagation for remote sensing and wireless communications. Use spectrum analyzers, swept frequency generators, frequency counters, couplers, detectors, slotted lines and network analyzers to develop capability in support of design

	projects in VLF to 20 GHz range. Two- to three-person teams then choose own projects from antenna, distributed circuits, remote sensing, radio astronomy, satellite, wireless, ionospheric HF radio or related topics. Working model constructed and demonstrated; some funding available for project costs. **EE 168: Introduction to Digital Image Processing** Digital pictures today are all around us, on the web, on DVDs, and on digital satellite systems, for example. In this course we will investigate the creation and manipulation of digital images by computer. The course will consist of theoretical material introducing the mathematics of images and imaging, as well as computer laboratory exercises designed to introduce methods of real-world data manipulation. The format will consist of lectures on Mondays and Wednesdays, with Fridays devoted to lab exercises. The lab exercises will introduce various image processing topics, which will be examined in more detail in the homework assignments. Topics will include representation of two-dimensional data, time and frequency domain representations, filtering and enhancement, the Fourier transform, convolution, interpolation, color images, and techniques for animation. **EE 189B: Software Project** **EE 206: Control System Design and Simulations** **EE 256: Numerical Electromagnetics** The principles and applications of numerical techniques for solving practical electromagnetics problems. Time domain solutions of Maxwells Equations. Finite Difference Time Domain (FDTD) methods. Numerical stability, dispersion, and dissipation. Step and pulse response of lossy transmission lines and interconnects. Absorbing boundary conditions. FDTD modeling of propagation and scattering in dispersive media. Near-to-far-zone transformations. Moment method solutions of integral equations, with applications to antenna problems. Computational problems require programming and use of MATLAB and other tools.

School Name	University of California – Berkeley
Data Source	"Degree Programs" (http://www.eecs.berkeley.edu/Programs/Notes/newnotes.shtml)
Classification	Capstone Certified
Program Description	Students are required E 190 and at least one of the elective design courses listed. (a course in another engineering department having substantial engineering design content can be substituted by petition) There appears to be no course in the curriculum that addresses professional practice issues.
Course Descriptions	**E 190: Technical Communication** After a brief review of grammar, the course focuses on the structure and organization of documents common in the engineering industry as students learn to develop rhetorical strategies for producing competent reports, proposals, formal descriptions, and instructions. Students in E190 also gain in-depth experience with oral presentations. Through group and individual work, students can work with traditional and electronic tools commonly used in professional settings. **EE 129: Neural and Nonlinear Information Processing** Principles of massively-parallel real-time computation, optimization, and information processing via nonlinear dynamics and analog VLSI neural networks. Applications selected from image processing, pattern recognition, feature extraction, motion detection, data compression, secure communication, bionic eyes, auto waves, and Turing patterns. **EE 130: Integrated Circuit Devices** Overview of electronic properties of semiconductor. Metal-semiconductor contracts, pn junctions, biopolor transistors, and MOS field-effect transistors. Properties that are significant to device operation for integrated circuits. Silicon device fabrication technology. **EE 140: Linear Integrated Circuits** Single- and multiple-stage transistor amplifiers. Operational amplifiers. Feedback amplifiers; 2-port formulation; source, load and feedback network loading. Frequency response of cascaded amplifiers, gain-bandwidth exchange, compensation, dominant-pole techniques, root

	locus. Supply- and temperature-independent biasing and references. Selected applications of analog circuits, such as analog-to-digital converters, switched-capacitor filters, and comparators. The laboratory builds on the concepts presented in the lectures and provides hands-on design experience and help with the use of computer-aided design tools such as SPICE. **EE 141: Digital Integrated Circuits** CMOS devices and deep sub-micron manufacturing technology. CMOS inverters and complex gates. Modeling of interconnect wires. Optimization of designs with respect to a number of metrics: cost, reliability, performance, and power dissipation. Sequential circuits, timing considerations, and clocking approaches. Design of large system blocks, including arithmetic, interconnect, memories, and programmable logic arrays. Introduction to design methodologies, including hands-on-experience. **EE 143: Microfabrication Technology** Integrated circuit device fabrication and surface micromatching technology. The mal oxidation, ion implantation, impurity diffusion, film deposition, epitaxy, lithography, etching contacts and intern connections, and process integration issues. Device design and mask layout, relation between physical structure and electrical/mechanical performance. MOS transistors and poly-Si surface microstructures will be fabricated in the laboratory and evaluated. **EE 145L: Introductory Electronic Transducer Lab** Laboratory exercises exploring a variety of electronic transducers for measuring physical quantities such as temperature, force, displacement, sound, light, ionic potential; the use of circuits for low-level differential amplification and analog signal processing; and the use of microcomputers for digital sampling and display. Lectures cover principles explored in the laboratory exercises; construction, response and signal to noise of electronic transducers and actuators; and design of circuits for sensing and controlling physical quantities. **EE 145M: Introductory Microcomputer Interfacing** Laboratory exercises constructing basic interfacing circuits and writing 20-100 line C programs for data acquisition,

	storage, analysis, display, and control. Use of the IBM PC with microprogrammable digital counter/timer, parallel I/O port, and analog I/O port. Circuit components include anti-aliasing filters, the S/H amplifier, A/D and D/A converters. Exercises include effects of aliasing in periodic sampling, fast Fourier transforms of basic waveforms, the use of the Hanning filter for leakage reduction, Fourier analysis of the human voice, digital filters, and control using Fourier deconvolution. Lectures cover principles explored in the laboratory exercises and design of microcomputer-based systems for data acquisition, analysis, and control. **CS 169: Software Engineering** Ideas and techniques for designing, developing, and modifying large software systems. Function-oriented and object-oriented modular design techniques, designing for re-use and maintainability. Specification and documentation. Verification and validation. Cost and quality metrics and estimation. Project team organization and management. Students will work in teams on a substantial programming project. **CS 184: Foundations of Computer Graphics** Techniques of modeling objects for the purpose of computer rendering: boundary representations, constructive solid geometry, hierarchical scene descriptions. Mathematical techniques for curve and surface representation. Basic elements of a computer graphics rendering pipeline; architecture of modern graphics display devices. Geometrical transformations such as rotation, scaling, translation, and their matrix representations. Homogeneous coordinates, projective and perspective transformations. Algorithms for clipping, hidden surface removal, rasterizatation, and anti-aliasing. Scan-line based and ray-based rendering algorithms. Lighting models for reflection, refraction, transparency. **CS 186: Introduction to Database Systems** Access methods and file systems to facilitate data access. Hierarchical, network, relational and object-oriented data models. Query languages for models. Embedding query languages in programming languages. Database services including protection, integrity control and alternative views of data. High level interfaces including application generators, browsers and report writers. Introduction to

	transaction processing. Database system implementation to be done as term project.

School Name	California Institute of Technology
Data Source	“Option Requirements” (http://www.ee2.caltech.edu/Academics/opt_req.html) “2004 – 2005 CalTech Catalog” (http://pr.caltech.edu/catalog/pdf/catalog_04_05.pdf)
Classification	Capstone
Program Description	Students are required to take at least one of the elective design courses listed. There appears to be no course in the curriculum that addresses professional practice or technical writing issues.
Course Descriptions	**EE/CS 80 abc Senior Thesis** Individual research project, carried out under the supervision of a member of the electrical engineering or computer science faculty. Project must include significant design effort. Written report required. **EE 91 ab Experimental Projects in Electronic Circuits** An opportunity to do advanced original projects in analog or digital electronics and electronic circuits. Selection of significant projects, the engineering approach, modern electronic techniques, demonstration and review of a finished product.

School Name	University of Illinois – Champaign-Urbana
Data Source	"Undergraduate Curriculum" (http://www.ece.uiuc.edu/ugrad/undergrad.html)
Classification	Capstone
Program Description	Students are required to take ECE 445. There appears to be no course in the curriculum that addresses professional practice or technical writing issues.
Course Descriptions	**ECE 445: Senior Design Project Laboratory** Individual design projects in various areas of electrical and computer engineering; projects are chosen by students with approval of the instructor; a written report, prepared to journal publication standards, and an oral presentation are required.

School Name	Georgia Institute of Technology
Data Source	"EE/CmpE Major Design Experience" (http://www.ece.gatech.edu/academics/undergrad/ mjr_design.html)
Classification	Capstone Certified
Program Description	Students are required to take ECE 4000 and at least one of the elective design courses listed. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**ECE 4000: Project Engineering & Professional Practice** Project engineering techniques and professional practice issues. Design methods and tools, product life-cycle, professional communication skills, ethical issues in electrical/computer engineering. **ECE 4005: ECE Design Project** Team-oriented major design project in electrical/computer engineering, incorporating engineering standards and realistic design constraints. Requires formal reports and oral presentations. **ECE 4006: Major Design Project** Team-oriented major design project in electrical/computer engineering. Incorporating engineering standards and realistic design constraints. Requires formal reports and oral presentations. **ECE 4010: Computer Engineering Design** Team-oriented major computer engineering design project, including hardware/software integration and trade-offs, engineering standards, and realistic design constraints. Formal reports and oral presentations. **ECE 4020: Bioengineering Design** Students will work in teams on bioengineering design projects. Course lectures will address topics related to the art of the design process and the practical design issues facing the bioengineer. **ECE 4025: Real-Time DSP Implementations Using DSP Microprocessors** A team-oriented design course in which students will address all aspects of the total implementation of real-time DSP systems from DSP algorithms to real-time I/O.

	ECE 4030: Energy System Design Design practices related to power system generation, transmission, and distribution systems. Study of related standards and guides. **ECE 4035: Electromagnetics Design** Design and evaluation of electromagnetic systems working at radio or microwave frequencies. Typical projects involve antennas, passive and active microwave devices, radio wave propagation, etc. **ECE 4040: Electronics Design Project** The design, analysis, and testing of electronic circuits and systems in a realistic environment. Engineering teams will be formed to design and test various systems. **ECE 4050: Fiber Optic System Design** A multi-disciplinary senior design course. Design, evaluation, construction, and testing of components to be assembled into an evolving student-built fiber communication system. **ECE 4055: Systems and Controls II - State Space Design** Major design course in control. Projects will include transducer design and modeling, control effort limitations, and performance versus cost. Collaboration with manufacturing and bioengineering encouraged.

School Name	University of Michigan – Ann Arbor
Data Source	"Program Advising Handbook" (http://www.eecs.umich.edu/eecs/undergraduate/ugee/handbk.html) "EECS Course Descriptions" (http://www.engin.umich.edu/students/current/academics/courses/eecs.pdf)
Classification	Capstone Certified
Program Description	Students are required to take EECS 496, TCHNCLCM 469, and at least one of the elective design courses listed.
Course Descriptions	**EECS 496: Major Design Experience Professionalism** Design principles for multidisciplinary team projects, team strategies, entrepreneurial skills, ethics, social and environmental awareness, and life long learning. Each student must take (simultaneously) Tech Comm 496 and one of the approved 400-level team project courses in computing. **TCHNCLCM 496: Adv. Technical Communication** **EECS 411: Microwave Circuits I** Transmission-line theory, microstrip and coplanar lines, S-parameters, signal-flow graphs, matching networks, directional couplers, low-pass and band-pass filters, diode detectors. Design, fabrication, and measurements (1-10GHz) of microwave-integrated circuits using CAD tools and network analyzers. **EECS 413: Monolithic Amplifier Circuits** Analysis and design of BJT and MOS multi-transistor amplifiers. Feedback theory and application to feedback amplifiers. Stability considerations, polezero cancellation, root locus techniques in feedback amplifiers. Detailed analysis and design of BJT and MOS integrated operational amplifiers. Lectures and laboratory. **EECS 425: Integrated Microsystems Laboratory** Development of a complete integrated microsystem, from functional definition to final test. MEMS-based transducer design and electrical, mechanical and thermal limits. Design of MOS interface circuits. MEMS and MOS chip fabrication. Mask making, pattern transfer, oxidation, ion implantation and metallization. Packaging and testing challenges. Students work in interdisciplinary teams.

	EECS 427: VLSI Design I Design techniques for rapid implementations of very large-scale integrated (VLSI) circuits, MOS technology and logic. Structured design. Design rules, layout procedures. Design aids: layout, design rule checking, logic, and circuit simulation. Timing. Testability. Architectures for VLSI. Projects to develop and layout circuits. **EECS 430: Radiowave Propagation and Link Design** Fundamentals of electromagnetic wave propagation in the ionosphere, the troposphere, and near the Earth. Student teams will develop practical radio link designs and demonstrate critical technologies. Simple antennas, noise, diffraction, refraction, absorption, multi-path interference, and scattering are studied. **EECS 438: Advanced Lasers and Optics Laboratory** Construction and design of lasers; gaussian beams; nonlinear optics; fiber optics; detectors; dispersion; Fourier optics; spectroscopy. Project requires the design and set-up of a practical optical system. **EECS 452: Digital Signal Processing Design Laboratory** Architectures of single-chip DSP processors. Laboratory exercises using two state-of-the-art fixed-point processors; A/D and D/A conversion, digital waveform generators, and real-time FIR and IIR filters. Central to this course is a team project in real-time DSP design (including software and hardware). **EECS 470: Computer Architecture** Basic concepts of computer architecture and organization. Computer evolution. Design methodology. Performance evaluation. Elementary queueing models. CPU architecture. Introduction sets. ALU design. Hardware and microprogrammed control. Nanoprogramming. Memory hierarchies. Virtual memory. Cache design. Input-output architectures. Interrupts and DMA. I/O processors. Parallel processing. Pipelined processors. Multiprocessors.

School Name	Carnegie Mellon University
Data Source	"B.S. Requirements/ECE Academic Guide" (http://www.ece.cmu.edu/users/shared/primer/index.php) "ECE Capstone Design Requirement" (http://www.ece.cmu.edu/users/shared/primer/details/capstone.php)
Classification	Capstone Certified
Program Description	Students are required to take at least one of the elective design courses listed. There appears to be no course in the curriculum that addresses professional practice or technical writing issues.
Course Descriptions	**18-517: Data Storage Systems Design** This course gives students a comprehensive understanding of data storage systems through lecture and simulation exercises. Over the course of the semester, students will work in teams to build a computer simulation of an entire disk drive recording channel, and observe the different forms that the stored information takes on its passage through a non-volatile storage system. As many realistic aspects of the storage system will be incorporated in the simulation as possible, including magnetic media hysteresis, magnetic and electronic noise, magnetoresistive readback sensors, and various methods of data detection. The class will culminate with demonstrations by each group of their models, and the effect the changes in recording parameters have on data integrity. Currently the SIMULINK package is used with Matlab to construct the simulation, and students are provided with a 3 hr. recitation period each week during which they can work on their simulation under the supervision of the course instructors. **18-525: Integrated Circuit Design Project** Integrated Circuit Design Project (18-525) is intended to provide the electrical and computer engineering student with IC design experience. It solidifies theoretical background and practical skills gained in 18-322. The primary stress of the 18-525 class will be on the IC design process as a whole. Such a process, seen as a sequence of design decisions, must lead to a design which optimizes a given objective function under a number of constraints. The optimum design must be achieved using a number of variables involving all levels of design abstraction and ranging between architecture choice and detail of the IC layout. Typical design objectives adopted in 18-525 designs

will be IC performance (throughput, clock frequency, etc.) and typical constraints will be die size and minimum feature size. The second most important objective of 18-525 is to mimic a large design team environment in which individual designers must: (a) communicate precisely and efficiently his/her ideas and (b) utilize any feedback provided by the "design environment". This objective will be achieved through class presentations given by each student and by stressing the importance of design documentation.

18-540: Rapid Prototyping of Computer Systems
This is a project-oriented course which will deal with all four aspects of project development; the application, the artifact, the computer-aided design environment, and the physical prototyping facilities. The class, in conjunction with the instructors, will develop specifications for a mobile computer to assist in inspection and maintenance. The application will be partitioned between human computer interaction, electronics, industrial design, mechanical, and software components. The class will be divided into groups to specify, design, and implement the various subsystems. The goal is to produce a working hardware/software prototype of the system and to evaluate the user acceptability of the system. We will also monitor our progress in the design process by capturing our design escapes (errors) with the Orthogonal Defect Classification (ODC). Upon completion of this course the student will be able to: generate systems specifications from a perceived need; partition functionality between hardware and software; produce interface specifications for a system composed of numerous subsystems; use computer-aided design tools; fabricate, integrate, and debug a hardware/software system; and evaluate the system in the context of an end user application.

18-544: Network Design and Evaluation
The purpose of the "Network Design and Evaluation" is to give students hands-on experience building networking software. A typical project will be the design, implementation, and evaluation of a network protocol. The design will specify the requirements, protocol specification, and success criteria. The implementation will have to work over an actual network, and the evaluation will evaluate whether the success criteria have been met. Students will

	work in teams and will have a choice of a small number of projects. **18-545: Advanced Digital Design Project** This is a term-project course oriented towards the development of skills to design large digital systems at a professional level. Proficiency gained in other software and hardware design courses will be utilized in the design and development of a System-on-a-Chip (SoC) prototype. Project development will utilize a mix of system architecture design, custom hardware design and software programming skills. The project will result in a prototype which will be built in a lab setting. Prototype development will include some wire-wrap and also the use of some state-of-the-art design tools. Industry standard practices of design reviews, final project presentations, and weekly reports will be followed. The design process will be studied. Through the project, class discussions, and interactions with classmates the course will allow you to enhance your effectiveness in future projects in industry or academia. **18-549: Distributed Embedded Systems** This advanced course considers embedded systems with multiple, distributed processing elements connected by a real-time network. These distributed embedded systems are becoming very common in application areas as diverse as transportation, medical equipment, industrial control, and household appliances. The course is divided into three phases: (1) the fundamentals of distributed system architecture and design approaches, (2) real-time embedded networks and system-wide scheduling, and (3) dependable system design. A semester-long course project, such as a detailed distributed implementation of an elevator simulation, is used to tie together the various aspects of the lecture material. While a significant understanding of hardware organization and operation is assumed, the focus of the course is mainly on software, simulation, and embedded network issues. Relevant aspects of the Unified Modeling Language (UML) are included, although this is not an in-depth course on that topic. 1 hour of the lecture periods per week is primarily used for discussion of non-testable advanced topics and talks by visitors from industry. **18-551: Digital Communications and Signal Processing**

	Systems Design This course provides the student with a rich, in-depth design and application hardware project experience in the areas of digital communications and/or signal processing systems using DSP hardware. Teams of students work on a semester-long project of their choice. Topics include: speech and music processing, digital communications, multimedia processing, data compression, data storage, wireless communications, CD, image and/or signal processing, etc. One month of introductory laboratories familiarize the students with DSP hardware and support software. Lectures address z-transforms, IIR and FIR filter design using MATLAB and DSP hardware, LPC and adaptive filters, channel coding, time and frequency multiplexing, short time Fourier and wavelet transforms, and spread spectrum techniques. **18-575: Control System Design** A capstone design elective in Electrical and Computer Engineering integrating the computer-aided analysis and design of feedback control systems from both the classical (transfer function) and modern (state-space) points of view. The perspective spans the dynamic modeling of physical systems and the analysis and computer-aided design (utilizing MATLAB) of linear and nonlinear, continuous-time and discrete-time, robust multivariable feedback systems. In illustrating the centrality of numerical linear algebra in control engineering, case studies are selected from servomechanism and linear-quadratic design and Kalman filtering. A significant emphasis is placed upon student selected design projects. **18-578: Mechatronic Design** Mechatronics is the synergistic integration of mechanism, electronics, and computer control to achieve a functional system. Because of the emphasis upon integration, this course will center around system integration in which small teams of students will configure, design, and implement a succession of mechatronic subsystems, leading to a main project. Lectures will complement the laboratory experience with comparative surveys, operational principles, and integrated design issues associated with the spectrum of mechanism, electronics, and control components. Class lectures will cover topics intended to complement the laboratory work, including mechanisms,

	actuators, motor drives, sensors and electronic interfaces, microcontroller hardware and programming and basic controls. During the first week of class, each student will be asked to complete a questionnaire about their technical background. The class will then be divided into multi-disciplinary teams of three students. During the first half of the class, lab assignments will be made every 1-2 weeks to construct useful subsystems based on material learned in lecture. The lab assignments are geared to build to the main project. **18-723: RFIC Design and Implementation** This course covers the design and analysis of radio-frequency integrated systems at the transistor level using state-of-the-art CMOS and bipolar technologies. It focuses on system-level trade-offs in transceiver design, practical RF circuit techniques, and physical understanding for device parasitics. Accurate models for active devices, passive components, and interconnect parasitics are critical for predicting high-frequency analog circuit behavior and will be examined in detail. The course will start with fundamental concepts in wireless system design and their impact on design trade-offs in different transceiver architectures. Following that, RF transistor model passive matching networks will be discussed. Noise analysis and low-noise amplifier design are studied next. The effects of nonlinearity are treated along with mixer design techniques. Practical bias circuit for RF design will be illustrated. Then, the importance of phase noise and VCO design will be considered together. The course will conclude with a brief study of frequency synthesizer and power amplifier design. **18-725: Digital Integrated Circuit Design** The purpose of this course is to study the design process of VLSI CMOS circuits. This course covers all the major steps of the design process, which include: logic, circuit and layout design. A variety of computer-aided tools are discussed and used in class. The main objective of this course is to provide VLSI design experience that includes design of basic VLSI CMOS functional blocks, verification of the design, testing and debugging. During the course, one complex VLSI project is submitted for fabrication. **18-744: Hardware System Engineering** This course focuses on the design and engineering of

	hardware systems. The core of this course is based on a large microprocessor design project carried out in student teams where each team is responsible for the detailed design of a module that must work correctly with the rest of the pieces. Students will gain in-depth understanding of computer architecture concepts through hands-on design and also acquire a broader perspective of how the different elements interact. The students will learn and experience the full engineering cycle of specification, implementation, validation and analysis, both within a module and across the whole system. Issues such as teamwork, risk and time management are also part of the course. Projects will be executed in Verilog, SystemC and an experimental operation-centric high-level hardware description language. This course requires substantial independent lab hours outside of the classroom.

School Name	Purdue University – West Lafayette
Data Source	"EE/CmpE Degree Requirements & Sample POS" (http://posserver.ecn.purdue.edu/eceugo/) "Course Information" (http://www.courses.purdue.edu)
Classification	Capstone
Program Description	Students are required to take at least one of the elective design courses listed. There appears to be no course in the curriculum that addresses technical writing.
Course Descriptions	**ECE 402: ECE Design Projects** Lecture sessions provide the student with background information on the design and management of projects. Formal lectures cover, for example, design for manufacturability, design for quality, test and evaluation, reliability and ethics, patents and copyrights, plus case studies. During the laboratory sessions, the students work in teams on a challenging open-ended electrical engineering project that draws on previous coursework. Projects routinely involve standard design facets (such as consideration of alternative solutions, feasibility considerations, and detailed system descriptions) and include a number of realistic constraints (such as cost, safety, reliability, and aesthetics). **ECE 477: Digital Systems Senior Project** A structured approach to the development and integration of embedded microcontroller hardware and software that provides senior-level students with significant design experience applying microcontrollers to a wide range of embedded systems (e.g., instrumentation, process control, telecommunications, intelligent devices, etc.). The primary objective is to provide practical experience developing integrated hardware and software for embedded microcontroller systems in an environment that models one which students will most likely encounter in industry. **ECE 490: Senior Participation in Engineering Projects in Community Service** Together, EPICS courses (ECE 290, 390, and 490 in ECE and corresponding courses in other participating departments) create a vertical project track under which students work in teams on long-term engineering projects. Each team consists of a mix of freshman, sophomores, juniors, and seniors. Projects of at least one year in duration

	are intended to solve real problems that are defined in consultation with "customers" from community service and educational organizations.

School Name	Cornell University
Data Source	“ECE Undergraduate Handbook” (http://www.ece.cornell.edu/ugradhndbk/main.htm) “Courses” (http://www.ece.cornell.edu/courses.cfm?view_all=true)
Classification	Capstone Certified
Program Description	Students must take at least two of the elective design courses listed. There appears to be no course in the curriculum that addresses professional practice issues. Technical writing requirements are satisfied by taking either a technical writing course from a pre-approved list or an engineering course that is deemed “writing intensive.”
Course Descriptions	**ECE 402: Biomedical System Engineering** Course introduces techniques of measuring and conditioning low-level (biological) signals. Topics include special signal to noise improvement circuits for analog signals, techniques to remove common-mode and correlated noise, and computer-aided techniques for analyzing sampled data. Final 6 or 7 weeks devoted to designing/prototyping a safe and effective "ambulatory microprocessor-controlled blood pressure monitor." Formal design document is required. ECE 402 is a culminating design experience (CDE) course. **ECE 415: Global Position System Theory** The Global Positioning System is analyzed in the context of system design and receiver operation. The course consists of lectures, laboratories, and a design project based on a GPS engine development system and covers receiver design and function, the navigation solution, and error sources. ECE 415 is a culminating design experience (CDE) course. **ECE 437: Fiber and Integrated Optics** Physical principles of optical waveguides. Wave equation solutions to the mode structure in waveguides, numerical analysis, mode coupling, dispersion and bandwidth limitations, optical materials, photonic band gap structures. Project design of planar optical components. ECE 437 is a culminating design experience (CDE) course. **ECE 446: Digital Communications Over Packet-Switched Networks** Design of performance analysis of communication systems

	operating over packet-switched networks. This is a basic course in networking that aims to bridge the gap between a classical networking class, and a classical digital communications class. The course is lab oriented, with a strong emphasis placed on programming assignments (both C and Matlab). Examples of topics that are covered include data compression, error control in networks, and network algorithms. ECE 446 is a culminating design experience (CDE) course. **ECE 453: Analog Integrated Circuit Design** Overview of devices available to analog integrated-circuit designers in modern CMOS and BiCMOS processes: resistors, capacitors, MOS transistors, and bipolar transistors. Basic building blocks for linear analog integrated circuits: single-stage amplifiers, current mirrors, and differential pairs. Transistor-level design of linear analog integrated circuits, such as operational amplifiers and operational transconductance amplifiers. Layout techniques for analog integrated circuits. Throughout the course, emphasis is placed on design-oriented analysis techniques. ECE 453 is a culminating design experience (CDE) course. **ECE 457: Silicon Device Fundamentals** Semiconductor carrier statistics, band diagrams, transport and their applications in diodes, MOSFET, and BJT. Emphasis is put on the CMOS operations for advanced VLSI technology. Six labs cover device measurements and design by simulation. By using the combined simulation and measurement, the course culminates in a comprehensive design project dealing with technical concerns in current VLSI industry as well as its economical, environmental, and social impacts. ECE 457 is a culminating design experience (CDE) course. **ECE 474: Digital VLSI Design** This is a two semester course and must be taken for Fall AND Spring. 5 credits (fall 4, spring 1). Students will receive an R grade until they test their chips in the spring. Introduction to digital VLSI design. Topics include basic transistor physics, switching networks and transistors, combinational and sequential logic, latches, clocking strategies, domino logic, PLAs, memories, physical design, floor planning, CMOS scaling, and performance and power

	considerations, etc. Lecture and homework topics emphasize disciplined design, and include: CMOS logic, layout, and timing; computer-aided design and analysis tools; and electrical and performance considerations. Students tape out a small project that is tested in the following semester. The course also includes an introduction to asynchronous design. ECE 474 is a culminating design experience (CDE) course. **ECE 475: Computer Architecture** Topics include instruction set principles, advanced pipelining, data and control hazards, multi-cycle instructions, dynamic scheduling, out-of-order execution, speculation branch prediction, instruction-level parallelism, and high-performance memory hierarchies. Students learn the issues and tradeoffs involved in the design of modern microprocessors. Labs involve the design of a processor and cache subsystem at the RTL level. ECE 475 is a culminating design experience (CDE) course. **ECE 476: Digital Systems Design Using Microcontrollers** Design of real-time digital systems using microprocessor-based embedded controllers. Students working in pairs design, debug, and construct several small systems that illustrate and employ the techniques of digital system design acquired in previous courses. The content focuses on the laboratory work. The lectures are used primarily for the introduction of examples, description of specific modules to be designed, and instruction in the hardware and high-level design tools to be employed. ECE 476 is a culminating design experience (CDE) course. **ECE 488: RF Circuits & Systems** Basic RF circuits and applications. Receivers, transmitters, modulators, filters, detectors, transmission lines, oscillators, frequency synthesizers, low-noise amplifiers. Applications include communication systems, radio and television broadcasting, radar, radio, and radar astronomy. Computer-aided circuit analysis. Five laboratory sessions. ECE 488 is a culminating design experience (CDE) course.

School Name	University of Texas – Austin
Data Source	"2004 – 2006 Electrical/Computer Engineering Curriculum" (http://www.ece.utexas.edu/undergrad/)
Classification	Capstone
Program Description	Students must take one of the following variants of the same design course. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**EE 464K: Senior Design Project** Design and experimental projects in electrical and computer engineering; the ethics of design for product safety and reliability; emphasis on written and oral reporting of engineering projects. This is the standard version of the senior lab. Students typically do a project that is usually specified by the course staff in their area of interest. However, proposals are welcome for projects. Student-proposed projects are permitted subject to technical merit, suitable subject and scope, and resources available. **EE 464H: Honors Senior Design Project** Design and experimental projects in departmental research laboratories; the ethics of design for safety and reliability; emphasis on written and oral reporting of engineering projects. This is the honors version of the senior lab. If you are in the top 10% of the senior class, you will receive an invitation to take this course. If your overall GPA is above 3.5, you are welcome to apply if you have a suitable project in mind and can find an interested professor. The idea here is for you to provide your own project under faculty sponsorship that you arrange, or you can work on with a faculty member on a project that they suggest. Schedule and reporting activities are the same as under "K". Grading is by the 464 staff with significant input from faculty sponsor or supervisor. **EE 464C: Corporate Senior Project** Design and experimental projects in departmental research laboratories; the ethics of design for safety and reliability; emphasis on written and oral reporting of engineering projects. EE 464C is designed for students who are permanent employees of a local company who are pursuing the BSEE degree on a full or part-time basis. The course is credited towards the BSEE degree the same as 464K or 464H. The 464C student works on a suitable design project

	that his or her employer has a strong interest in and toward which the employer is willing to provide financial, equipment, time, and supervisory resources. The student must have day-to-day supervision at work on this project as well as the oversight of an ECE faculty member and a 464 TA on a weekly basis. The "C" format implies that the work will be done at the work site of your employer and that this site is in the Austin area and may be visited by the TA and Professor.

School Name	Princeton University
Data Source	"The Electrical Engineering Handbook" (http://www.ee.princeton.edu/undergrad/ug_book01-02.php) "The Undergraduate Announcement" (http://www.princeton.edu/pr/catalog/ua/05/442.htm)
Classification	Capstone Certified
Program Description	Students must take at least one of the elective design courses listed. An independent research project may satisfy this criterion if it is deemed to have "substantial design content." There appears to be no course in the curriculum that addresses professional practice or technical writing issues.
Course Descriptions	**ELE 318: Microprocessor-Based System Design** **ELE 352: Physical Optics** Fundamental and practical aspects of physical optics. Lenses and ray optics, lens makers formula, wave propagation, Fourier optics, Gaussian beams are all considered. Design and use of practical optical systems including optical beam steering in medicine, fiber optics. **ELE 375: Computing Structures** An introduction to computer architecture and organization. Instruction set design; basic processor implementation techniques; performance measurement; caches and virtual memory; pipelined processor design; RISC architectures; design trade-offs among cost, performance, and complexity. **ELE 401: Analog Electronics** Bipolar and field effect transistors; operational amplifiers; general feedback amplifiers; low- and high-power amplifiers; differential amplifiers; amplifier chains; high-frequency models; D/A and A/D integrated circuits; computer-aided circuit modeling. **ELE 402: Digital Electronics** Application of semiconductor devices to the implementation of digital logic functions, with an emphasis on integrated circuits. MOS and bipolar transistor operation and their use in logic families such as NMOS, CMOS, TTL, ECL. Static and dynamic circuits. Speed, power, layout, area, and other performance tradeoffs, computer

simulation. Principles of semiconductor memory circuits (ROM, SRAM, DRAM, EPROM, and others).

ELE 412: Electrical Engineering Design Laboratory
A project-oriented design laboratory. Topics may include analog and digital electronic systems, feedback control systems, power electronic systems, microprocessor system applications, digital control systems, computer simulation as a design tool, and communication systems. Emphasis will be on a systematic approach to design and the implementation or simulation of the resulting design project.

ELE 453: Optical Electronics
Electromagnetic waves. Gaussian beams. Optical resonators. Interaction of light and matter. Lasers. Mode locking and Q-switching in lasers.

ELE 454: Photonics and Lightwave Communications
Introduction to fiber-optic communication systems. Optical detectors and receivers. Design and performance of direct detection systems. Coherent light wave systems. Multichannel WDM communication systems. Optical amplifiers. Soliton communication systems.

ELE 462: Design of VLSI Systems
The implementation of digital systems using integrated circuit technology. Emphasis on structured design methodologies for VLSI systems. Topics include: design rules for metal oxide semiconductor (MOS) integrated circuits, implementation of common digital components, tools for computer-aided design, novel architectures for VLSI systems.

ELE 463: Computer-Aided Design of Systems
Algorithms and methodologies for the synthesis, analysis, and verification of digital systems. Topics include layout synthesis, logic synthesis, sequential synthesis, and data management.

ELE 464: Embedded Systems

ELE 465: Switching and Sequential Systems
Theory of digital computing systems. Topics include logic function decomposition, reliability and fault diagnosis,

	synthesis of synchronous circuits and iterative networks, state minimization, synthesis of asynchronous circuits, state-identification and fault detection, finite-state recognizers, definite machines, information lossless machines. **ELE 475: Computer Architecture** An in-depth study of the fundamentals of modern processor and system design. Students will develop a strong practical and theoretical background in the technical and economic issues that govern the design of computer architectures and implementations. The course will emphasize the skills required to design and evaluate current and future systems. **ELE 482: Digital Signal Processing** The processing of signals by digital techniques, including general purpose computers and dedicated processors. Topics include discrete-time signal and system theory, the design and implementation of FIR and IIR digital filters, Fast Fourier Transforms, finite word-length effects, and applications to speech, picture processing, and data communications. **ELE 483: Feedback Systems** The study of automatic control systems. Classical scalar input-output analysis and design using root locus and graphical techniques in the frequency domain. Modern multiple input-output analysis and design using state space methods and optimization theory. **ELE 488: Image Processing and Transmission** Introduction to the basic theory and techniques of two- and three-dimensional image processing. Topics include image perception, 2-D image transforms, enhancement, restoration, compression, tomography and image understanding. Applications to HDTV, machine vision, and medical imaging, etc.

School Name	Johns Hopkins University
Data Source	“Undergraduate Advising Manual for 2005 – 2006” (http://www.ece.jhu.edu/%7Egglm/manuals/EE-man.htm) “Undergraduate Course Descriptions” (http://www.ece.jhu.edu/Undergraduate/ugrad_desc.shtml)
Classification	Capstone Certified
Program Description	Students must take at least two of the elective design courses listed. There appears to be no course in the curriculum that addresses professional practice or technical writing issues. (While writing-intensive coursework is required, courses focused in technical communications and writing are only suggested.)
Course Descriptions	**520.424: FPGA Synthesis Laboratory** An advanced laboratory course in the application of FPGA technology to information processing, using VHDL synthesis methods for hardware development. The student will use commercial CAD software for VHDL simulation and synthesis, and implement their systems in programmable XILINX 20,000 gate FPGA devices. The lab will consist of a series of digital projects demonstrating VHDL design and synthesis methodology, building up to final projects at least the size of an 8-bit RISC computer. Projects will encompass such things as system clocking, flip-flop registers, state-machine control, and arithmetic. The students will learn VHDL methods as they proceed through the lab projects, and prior experience with VHDL is not a pre-requisite. **520.425: FPGA Projects Laboratory** Laboratory course for FPGA based senior projects. Students will work in teams to complete a design project that makes use of embedded FPGAs. The projects will make use of the Spartan2 XSA boards and other resources from the FPGA Synthesis lab course. Possible projects include: A 16 or 32 bit RISC processor with student designed ISA architecture, assembler, and mini operating system; or a Spartan2 emulation of an existing microprocessor such as an 8051, an optical communication system to transmit stereo music using various modulation schemes for comparison (This would include FM or AM and at least one digital scheme such as FSK,); or a digital receiver for commercial AM or FM radio. Students are expected to complete a demonstration and produce a poster session final report.

	520.448: Electronics Design Laboratory An advanced laboratory course in which teams of students design, build, test and document application specific information processing microsystems. Semester long projects range from sensors/actuators, mixed signal electronics, embedded microcomputers, algorithms and robotics systems design. Demonstration and documentation of projects are important aspects of the evaluation process. **520.450: Advanced Microprocessor Design Laboratory** The course covers the interfacing of microprocessors to memory and peripherals. Topics include input/ output ports, timer operations, interrupt handling, serial communication, digital to analog and analog to digital conversions, and EEPROM programming. Student work is primarily software with some hardware hookup. **520.454: Control Systems Design** Classical and modern control systems design methods. Topics include formulation of design specifications, classical design of compensators, state variable and observer based feedback. Computers are used extensively for design, and laboratory experiments are included. **520.484: Optoelectronics Laboratory** This laboratory course involves designing and building optoelectronic circuits. Namely, laser diode drivers (CW and pulsed), oscillators, low-noise amplifier circuits, photodetector biasing circuits and active filters will be designed, built and tested. **520.487: Introduction to MEMS** **520.490: Analog and Digital VLSI Systems Architecture** **520.491: CAD of Digital VLSI Systems** An introductory course in which students, manually and through computer simulations, design digital CMOS integrated circuits and systems. The design flow covers transistor, physical, and behavioral level descriptions, using SPICE, Layout, and VerilogHD1 VLSI CAD tools. After design computer verification, students can fabricate and test their semester-long class projects.

	520.492: Mixed Signal VLSI Silicon models of information and signal processing functions, with implementation in mixed analog and digital CMOS integrated circuits. Aspects of structured design, scalability, parallelism, low-power consumption, and robustness to process variations. Topics include digital-to-analog and analog-to-digital conversion, delta-sigma modulation, bioinstrumentation, and adaptive neural computation. The course includes a VLSI design project. **520.495: Microfabrication Laboratory** This laboratory course is an introduction to the principles of microfabrication for microelectronics, sensors, MEMS, and other synthetic microsystems that have applications in medicine and biology. Course comprises of laboratory work and accompanying lectures that cover silicon oxidation, aluminum evaporation, photoresist deposition, photolithography, plating, etching, packaging, design and analysis CAD tools, and foundry services. **520.496/7: VLSI Design and Prototyping Workshop** Hands-on laboratory where students individually complete the design, layout, and testing of a VLSI circuit implementing a system-on-chip. Examples include CMOS computational imagers, video and speech coders, pattern recognition processors, and biointerfaces. Both semesters need to be completed in order to receive course credit. Chips are fabricated through MOSIS at the end of the first semester, and experimentally characterized in the second. Coursework includes in-class presentation of design and measured results. **520.498/9: Senior Design Project** Capstone design project, in which a team of students engineer a system and evaluate its performance in meeting design criteria and specifications. Example application areas are microelectronic information processing, image processing, speech recognition, control, communications and biomedical instrumentation. The design needs to demonstrate creative thinking and experimental skills, and needs to draw upon knowledge in basic sciences, mathematics and engineering sciences. Interdisciplinary participation, such as by biomedical engineering, mechanical engineering and computer science majors, is strongly encouraged.

School Name	Northwestern University
Data Source	“Undergraduate Study Manual 2004-2005” (http://www.ece.northwestern.edu/ugrad/manual2004/ ugrad_manual2004.html) “Course Descriptions” (http://www.ece.northwestern.edu/ course_descriptions.html)
Classification	Capstone Certified
Program Description	Students are required to take IDEA 106-1, IDEA 106-2, and at least one of the elective design courses listed. Students are also encouraged to take at least two credits of independent research as well. There appears to be no course in the curriculum that addresses professional practice or technical writing issues.
Course Descriptions	**IDEA 106-1,2: Engineering Design and Communications** Integrated introduction to the engineering design process and technical communication. Approaches to unstructured and poorly defined problems; conceptual and detailed design; team structure and teamwork; project planning; written, oral, graphical, and interpersonal communications; use of software tools; discussion of societal and business issues. **ECE 347: Microprocessor System Design** Programmable logic devices such as PAL, FPGA, etc. Design, prototype and test individual projects involving microprocessors and programmable logic devices. **ECE 362: Computer Architecture Project** Quarter long team project that entails designing a processor for a complete Instruction Set. Involves ISA design, design of components, datapath and control for a pipelined processor to implement the ISA. The design is performed using industry strength design tools and VHDL is used as the design specification language. The design is evaluated using benchmark programs for correctness and performance. **ECE 392: VLSI Design Projects** Design of a cutting-edge VLSI chip. Teams of 5 to 10 students undertake a large circuit design problem, going from specification to VLSI implementation while optimizing for speed, area, and/or power. Group

	collaboration and engineering design.

School Name	University of Wisconsin – Madison
Data Source	"Information for Current Undergraduates" (http://www.engr.wisc.edu/ece/current/undergrad/)
Classification	Capstone Certified
Program Description	Students are required to take at least one of the elective design courses listed. There appears to be no course in the curriculum that addresses professional practice or technical writing issues.
Course Descriptions	**ECE 409: Introductory Feedback Control** Concepts in modern feedback control applied to hardware-based design problems. This lab gives students a wide range of conceptual and hardware experience, rather than focusing on specific applications. Weekly exercises consist of theory, design, simulation, testing, and data analysis. **ECE 412: Power Electronic Circuits** Operating characteristics of power semiconductor devices such as Bipolar Junction Transistors, IGBTs, MOSFETs and Thyristors. Fundamentals of power converter circuits including dc/dc converters, phase controlled ac/dc rectifiers and dc/ac inverters. Practical issues in the design and operation of converters. **ECE 431: Digital Signal Processing** Sampling continuous-time signals and reconstruction of continuous-time signals from samples; spectral analysis of signals using the discrete Fourier transform; the fast Fourier transform and fast convolution methods; z-transforms; finite and infinite impulse response filter design techniques; signal flow graphs and introduction to filter implementation. **ECE 432: Digital Signal Processing Laboratory** Implementation of digital signal processing algorithms on special-purpose and general-purpose hardware. Use of assembly and high-level languages, and simulator to develop and test IIR, FIR filters and the FFT for modern DSP chips. Scaling for fixed point arithmetic. Use of high level languages to implement real time, object oriented component based DSP systems in general purpose computers. DSP applications, including data and voice communication systems.

	ECE 436: Communication Systems I Amplitude, frequency, pulse, and pulse-code modulation. Narrow-band noise representation and signal-to-noise ratios for various modulation schemes. Pulse shaping, timing recovery, carrier synchronization, and equalization. Sampling, quantization, and coding. **ECE 437: Communication System II** Statistical analysis of information transmission systems. Probability of error, design of receivers for digital transmission through additive white Gaussian noise channels and bandlimited channels. Spread spectrum communication systems. Channel capacity, source and error control coding. **ECE 439: Introduction to Robotics** A system engineering approach to robotic science and technology. Fundamentals of manipulators, sensors, actuators, end effectors and product design for automation. Kinematics, control, and programming of manipulators, along with introduction to pattern recognition and computer vision. **ECE 447: Applied Communications Systems** Analysis with design problems of electronic communications circuits. Emphasis on the nonlinear effects of large-signal operation of active devices. Complete design of r.f. oscillator, amplifier, and mixer circuits. **ECE 453: Embedded Microprocessor System Design** Lecture and Lab. Microprocessor and microcomputer structures and applications; programming and design of hardware interfaces; emphasis on student projects. **ECE 455: Communications Systems Laboratory** A series of experiments and a project demonstrating the fundamentals of modern electronic communication systems, including amplitude, single-sideband, frequency, and pulse modulation, and frequency and time division multiplexing. Applications include radio, telephone, television and radar systems. **ECE 462: Medical Instrumentation** Design and application of electrodes, biopotential amplifiers, biosensors, therapeutic devices. Medical

	imaging. Electrical safety. Measurement of ventilation, blood pressure and flow. Lecture and lab. **ECE 468: Digital Computer Projects in Control and Instrumentation** On-line and real-time applications of digital computers in instrumentation and control systems; design of hardware interfaces and software; emphasis on student projects. **ECE 491: Senior Design Project** Engineering design projects supervised by faculty members. Student (or group of students) must work with a faculty member to develop a proposal for the design project. A one page preliminary proposal must be signed by the faculty member and placed in student's file before the end of the second week of classes. A final written report is required; oral report and demonstration is at the option of the faculty supervisor. Faculty will establish a meeting schedule with the student(s) so that they monitor progress frequently (typically at least one meeting every two weeks). **ECE 512: Power Electronics Laboratory** This laboratory introduces the student to measurement and simulation of important operating characteristics of power electronic circuits and power semiconductor devices. Emphasis is on devices, circuits, gating methods and power quality. **ECE 531: Speech Signal Processing** Aerodynamic and acoustic mechanisms of sound production in speech. Multi-tube acoustic models of the vocal tract. Pitch detection, spectrographic analysis by Fourier and LPC methods. Speech synthesis, low bit rate speech coding, feature extraction for speech recognition. **ECE 532: Theory and Applications of Pattern Recognition** Pattern recognition systems and components; decision theories and classification; discriminant functions; supervised and unsupervised training; clustering; feature extraction and dimensional reduction; sequential and hierarchical classification; applications of training, feature extraction, and decision rules to engineering problems. **ECE 533: Image Processing**

Mathematical representation of continuous and digital images; models of image degradation; picture enhancement, restoration, segmentation, and coding; pattern recognition, tomography.

ECE 537: Communication Networks
Study of communication networks. Layered network architecture. Queueing theory: Little's theorem, M/ and M/G/1 queues, Jackson networks. Data link control: error detection, retransmission strategies, framing. Network layer: flow control (window flow control), routing (shortest-path routing, flow models, optimal routing). Multiaccess communications: random access and Aloha, carrier sensing, multiaccess reservations. Circuit switched networks.

ECE 539: Introduction to Artificial Neural Networks and Fuzzy Systems
Theory and applications of artificial neural networks and fuzzy logic: multi-layer perceptron, self-organization map, radial basis network, Hopfield network, recurrent network, fuzzy set theory, fuzzy logic control, adaptive fuzzy neural network, genetic algorithm, and evolution computing. Applications to control, pattern recognition, nonlinear system modeling, speech and image processing.

ECE 541: Analog MOS Integrated Circuit Design
Analysis, design and applications of modern analog circuits using integrated bipolar and field-effect transistor technologies. Provides the student with a working knowledge of the basic circuits used in modern analog integrated circuits and techniques for analysis and design.

ECE 543: Numerical Modeling of Semiconductor Devices and Processing
Study of semiconductor devices fabrication processes using advanced computer simulation tools. Specific devices are modeled from fabrication to electrical properties and parameters extraction. Deposition, lithography, etching, implant processes are discussed. Statistical methods are used to study the effect of process parameters (and variations) on device electrical properties.

ECE 545: Advanced Microwave Measurements and Communications

	Measurements at VHF and microwave frequencies; characteristics of microwave generators, amplifiers, passive devices and detection systems; measurement of frequency, noise and simple antenna patterns; time domain reflectometry, swept frequency network and spectrum analyzer techniques; lecture and lab. **ECE 547: Advanced Communications Circuit Design** Principles underlying the design of r.f. and microwave communications circuits. Analysis and design of wideband nonlinear power amplifiers, S-parameter techniques for r.f. active circuit design, computer aided design techniques, r.f. integrated circuits, fundamentals of low noise r.f. design. **ECE 548: Integrated Circuit Design** Bipolar and MOS devices in monolithic circuits. Device physics, fabrication technology. IC-design for linear and nonlinear circuitry. **ECE 549: Integrated Circuit Fabrication Laboratory** Monolithic integrated circuit fabrication; mask making, photolithography, oxidation, diffusion, junction evaluation, metallization, packaging, and testing. **ECE 551: Digital System Design and Synthesis** Introduction to the use of hardware description languages and automated synthesis in design. Advanced design principles. Verilog and VHDL description languages. Synthesis for hardware description languages. Timing-oriented synthesis. Relation of integrated circuit layout to timing-oriented design. Design for reuse. **ECE 553: Testing and Testable Design of Digital Systems** Faults and fault modeling, test equipment, test generation for combinational and sequential circuits, fault simulation, memory and microprocessor testing, design for testability, built-in self-test techniques, and fault location. **ECE 554: Digital Engineering Laboratory** Practical aspects of computer system design. Design, construction, and testing of significant digital subsystems. Design, construction, microprogramming, and programming of bit-slice implemented digital computers.

	ECE 555: Digital Circuits and Components Principles and characterization of logic circuits. Design and analysis techniques for applied logic circuits. Transmission lines in digital applications. Families of circuit logic currently in use and their characteristics. **ECE 556: Design Automation of Digital Systems** Use of digital computers to simulate, partition, place and interconnect digital electronic systems. **ECE 577: Automatic Controls Laboratory** Control theory is reduced to engineering practice through the analysis and design of actual systems in the laboratory. Experiments are conducted with modern servo systems using both analog and digital control. Systems identification and modern controls design are applied to motion and torque control.

School Name	Penn State – University Park
Data Source	"BSEE Degree Requirements" (http://www.ee.psu.edu/acadaff/undergrad/bseereq.html)
Classification	Capstone
Program Description	Students must take ENGL 202C and one of the two elective design courses.
Course Descriptions	**ENGL 202C: Technical Writing** Writing for students in scientific and technical disciplines. **ECE 402W: Senior Project Design in Electromagnetics** Project designs of antenna, microwave and optical systems, and computational methods in electromagnetics. EE 402W is intended to give senior-year electrical engineering students a "real-world simulation" of a total design experience. The focus is on electromagnetic engineering design applications such as antennas and filters, which are developed as semester projects. This is accomplished through both lectures and a laboratory component. One period each week is devoted to general lectures concerning professional engineering topics. The subjects of these lectures vary but generally are concerned with topics that are not purely technical in nature, such as laboratory safety, quality control, reliability, entrepreneurship, job interviewing, deciding to go to graduate school, ethics, etc.. **ECE 403W: Senior Project Design** Project designs of analog and digital systems, interfacing, and relevant electronic circuits, with an emphasis on technical communication skills. EE 403W is intended to give senior-year electrical engineering students a "real-world simulation" of a total design experience. This is accomplished through both lectures and a laboratory component. One period each week is devoted to general lectures concerning professional engineering topics. The subjects of these lectures vary but generally are concerned with "life as an engineer" topics that are not purely technical in nature. Topics typically include laboratory safety, quality control, reliability, entrepreneurship, job interviewing, deciding to go to graduate school, ethics, etc..

School Name	Rensselaer Polytechnic Institute
Data Source	"Senior Design Course Information" (http://www.ecse.rpi.edu/senior_advising_main.html) "Course Descriptions" (http://www.rpi.edu/academics/catalog/ pdf05-06/courses.pdf)
Classification	Capstone Certified
Program Description	Students are required to take ENGR 4010 and at least one of the elective design courses listed. There appears to be no course in the curriculum that addresses professional practice or technical writing issues.
Course Descriptions	**ENGR 4010: Professional Development III** Students will study issues associated with working in teams in a modern work environment. Various styles of leadership, the definitions of power and empowerment and their applications in industry and team settings will be studied. Additionally, other topics to be explored include vision, values and attitudes, and organizational culture. The course format will include small and large group discussions, case studies, experiential exercises, and regular participation from industry guests. **ECSE 4060: Inventor's Studio** Analysis and design of communications circuits, including coupling networks, oscillators, mixers, Class B and C r-f amplifiers; Class B and D broadband amplifiers; AM and FM modulators and demodulators; AGC and AFC and FSK circuits; pulse modulation techniques; phase-locked loops. **ECSE 4120: Electronic Circuits Design** This course integrates theory, computer simulation, and experimental laboratory work. Included are the principles of reliability and optimization. Projects include the design, simulation, practical implementation, and testing of electronic circuits. **ECSE 4260: Physical Design in Microelectronics** The conversion of circuit schematics to integrated-circuit chip layouts. Emphasis is on integrated circuits, device design, and the electrical performance of interconnected devices. Projects will involve the use of CAD software for process simulation, electrical analysis, physical placement, and interconnect routing.

	ECSE 4460: Control Systems Design Design principles include conceptual system design, components selection, modeling and simulation using computer-aided control design tools, and real-time programming. Each team will propose, design, evaluate, build, and test a working control system. **ECSE 4560: Signal Processing Design** Supervised design projects in digital signal processing. Project areas include receivers, synchronizers, parameter estimators, digital filters, voice and image processors. **ECSE 4780: Advanced Computer Hardware Design** Design methodologies include register transfer modules and firmware microprogrammed design. "Bit-slice" philosophy of design. LSI microprocessors as design elements in larger digital systems such as high-speed channels and special purpose computers. Detailed discussion of the structure of several computers at the chip and board level. Specification of custom IC digital systems. FPGA based design implementation using VHDL. **ECSE 4790: Microprocessor System Design** This course integrates hardware and software for real-time microprocessor based digital systems. Laboratory exercises are included to facilitate hardware and software development techniques practiced in industry. **ECSE 4900: Electrical, Computer, and Systems Engineering Design** Provides all ECSE majors senior design experience by engaging them in client sponsored projects. The students work in multidisciplinary teams, jointly responsible to the faculty, the client liaison, and to each other for project management, execution and reporting. Contemporary design tools and practices are emphasized. **ECSE 4980: Senior Design Project** This course can satisfy the EE or CSE capstone design requirement if certain conditions are met and approval is obtained from the ECSE Department Senior Design Coordinator. This is designated as a writing-intensive course. Guidelines for Senior Design Projects are available in the main ECSE office on the 6th floor of the JEC.

	Note for all capstone design courses: A capstone design course provides a curriculum-culminating major design experience. Students work in teams of three or more on open-ended projects with realistic constraints. The course is designated as writing intensive. Oral and written presentations are required. Course grade is based on team performance and individual contributions.

School Name	Texas A&M University – College Station
Data Source	"Undergraduate Curriculum" (http://www.ee.tamu.edu/Undergrad/UndCurriculum.htm) "Undergraduate Courses" (http://www.ee.tamu.edu/Undergrad/UndCourses.htm)
Classification	Capstone
Program Description	Students are required to take ENGL 301 and ELEN 405.
Course Descriptions	**ENGL 301: Technical Writing** Process of developing field-specific technical information related to the major, including researching, drafting, editing, revising, and designing technical reports, proposals, manuals, resumes and professional correspondence for specific audiences. Special topics, computer and distance sections available. **ELEN 405: Electrical Design Laboratory** Introduction to the design process and project engineering as practiced in industry; student teams apply the design process by developing a project from proposed through test and evaluation.

School Name	Rice University
Data Source	"Bachelor of Science Degree Requirements" (http://www.ece.rice.edu/academics/undergrad/bsdegreq/) "Courses Database" (http://webdb.ece.rice.edu/public-db/courses/)
Classification	Capstone Certified
Program Description	Students are required to take ELEC 493, ELEC 494, and at least one of the elective design courses listed. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**ELEC 493: Senior Design Seminar** Covers design methodology, project planning, engineering documentation, and other design related topics. Required of all students. **ELEC 494: Senior Design Laboratory** Teams of students will specify, design, and build a system to meet a prescribed set of requirements. A substantial document and a formal presentation describing the design will be required. Required of all students. **ELEC 422: VLSI Design** Study of VLSI technology and design and MOS devices, characteristics, and fabrication. Includes logic design and implementation, VLSI design methodology, circuit simulation, and verification, as well as group design projects. **ELEC 432: Digital Radio System Design** Analysis and design of digital radio communication systems including architectures, algorithms, hardware components, and system characterization. **ELEC 464: Photonic Sensor System Design** Presentation of the parameters and physics of using light to determine physical properties or state; principles and characteristics of photonic sources and detectors; team-based development of a photonic sensor design project for monitoring an environment, a process, a life form, a device, or a system, including data collection, analysis, verification, and appropriate action/control. **ELEC 491: Independent Design Project** Students who wish to pursue substantial, independent

	projects or participate in engineering design competitions should enroll in 491 as the first semester of their design sequence. All projects must be approved by the Undergraduate Curriculum Committee.

School Name	University of Minnesota – Twin Cities
Data Source	"Electrical Engineering Curriculum Guide" (http://www.ece.umn.edu/academics/ugrad-studies/ee/curr_guide_EE.pdf) "EE Class Pages" (http://www.ece.umn.edu/courses/ee/class/)
Classification	Capstone
Program Description	Students must take the capstone design course corresponding to their placement in the ECE program. There appears to be no course in the curriculum that addresses professional practice or technical writing issues.
Course Descriptions	**EE 4951W: Senior Design Project** Main objective: to learn engineering team design methodology. Secondary objectives: to refine oral presentation and technical writing skills. **EE 4981H-4982V: Senior Honors Project** The yearlong Senior Honors Project, carried out under a two-semester sequence, serves as a capstone design and research experience for a selected group of academically successful electrical engineering and computer engineering seniors. The primary aim of these courses is the training of independent, disciplined, and articulate research and design engineers, who are familiar with the formulation and conduct of experiments, knowledge of applications and an appreciation for the multidisciplinary and team-based approaches to solving technical problems and developing new techniques and technologies.

School Name	Virginia Institute of Technology
Data Source	“ECE Degree Programs and Requirements” (http://www.ecpe.vt.edu/ugrad/curriculum/index.html) “ECE Courses” (http://www.ecpe.vt.edu/ugrad/courses.html)
Classification	Capstone Certified
Program Description	All students must take ENGL 3764. Students enrolled in EE program must take at least one of the elective design courses, while those enrolled in the CPE program must take at least two. There appears to be no course in the curriculum that addresses professional practice issues.
Course Descriptions	**ENGL 3764: Technical Writing** Principles and procedure of technical writing; attention to analyzing audience and purpose, organizing information, designing graphic aids, and writing such specialized forms as abstracts, instructions, and proposals. **ECE 4104: Microwave and RF Engineering** Passive and active RF and microwave components and circuits for wireless communications: transmission-line theory; planar transmission-lines and waveguides; S-parameters; resonators; power dividers and couplers; microwave filters; sources, detectors, and active devices; modern RF & microwave CAD; measurement techniques. **ECE 4114: Antennas** Antenna fundamentals, analysis and design principles, and a survey of antenna types including: arrays, wire antennas, broadband antennas, and aperture antennas. **ECE 4164: GPS Theory and Design** Fundamental theory and applications of radio navigation with the Global Positioning System GPS. Satellite orbit theory, GPS signal structure and theory, point positioning with pseudoranges and carrier phases, selective availability, dilution of precision, differential GPS, atmospheric effect on GPS signals. **ECE 4206: Electronic Circuit Design** Stability and response of feedback amplifier, wideband amplifier, operational amplifier characteristics, waveform generators and wave shaping, nonlinear circuit applications, signal generators, and photolithography. Design of analog electronic circuits, circuit simulation, response

	characterization, and printed circuit construction. **ECE 4224: Power Electronics** Power devices and switching circuits including inverters and converters; electronic power processing and control as applied to industrial drives, transportation systems, computers, and spacecraft systems. **ECE 4304: Design in Power Engineering** Study principles in electric power engineering and apply them in design problems including: machine control and design, IT and Internet applications in power, expert systems and AI applications, power system protection and digital relaying, communication, and data transmission, solar and wind energy, computer-aided design and GUI, data over power lines. **ECE 4406: Control Systems** Introduction to sample data techniques for control system design. **ECE 4510: Genetic Algorithms and Evolutionary Design** Introduction to evolutionary computation and design, including genetic algorithms, genetic programming, evolutionary programming and evolution strategies. Applications in engineering optimization, digital systems design, automatic programming and knowledge discovery. **ECE 4514: Digital Design II** In this course, students will learn to use a hardware description language (VHDL) in the digital design process. Emphasis will be on system-level concepts and high-level design representations. Methods will be learned that are appropriate for use in automated synthesis systems. Students will have the opportunity to use commercial schematic capture and simulation tools to design a series of increasingly complex devices. Students will also use a logic synthesis tool and synthesize assignments into Field Programmable Gate Arrays. **ECE 4524: Artificial Intelligence and Engineering Applications** Problem solving methods; problem spaces; search techniques; knowledge representation; programming

	languages for AI; games; predicate logic; knowledge-based systems; machine learning; planning techniques; reactive systems; artificial neural networks; natural language understanding; computer vision; robotics. **ECE 4534: Embedded System Design** Microprocessor development systems, programming using assembly and higher-level languages. Implementation of embedded application algorithms. Details of a contemporary microprocessor architecture. Comparative analysis of advanced architecture and specialty architectures. Laboratory work is required. Software development including multiple memory models, device drivers, basic network principles including internet applications. **ECE 4540: VLSI Circuit Design** Introduction to the design and layout of Very Large Scale Integrated Circuits (VLSI). Emphasis is placed on digital CMOS circuits. Static and dynamic properties of MOSFET devices, along with integrated circuit fabrication are examined. Computer-aided design tools are used to produce working integrated circuit designs. **ECE 4550: Real-Time Systems** Introduction to real-time systems, real-time scheduling including multiprocessor scheduling, real-time operating systems (kernels), real-time communication, real-time programming languages, reliability and fault-tolerance, and real-time system requirements and design methods. Design, analysis, and implementation of real-time kernel mechanisms and real-time applications using kernels such as Linux and programming languages such as C (with POSIX primitives) and Ada 95. **ECE 4564: Network Application Design** Application program interface and network transport services including User Datagram Protocol and Transmission Control Protocol from the Internet protocol suite. Client-server organization and design of synchronous, asynchronous, and multithreaded client and server applications. Design, implementation, and testing techniques to improve robustness and performance. Design and implementation of servers and clients for standard Internet application protocols. Partially duplicates CS 4254

	and credit will not be allowed for both. **ECE 4570: Wireless Networks and Mobile Systems** Multidisciplinary, project-oriented design course that considers aspects of wireless and mobile systems. Including wireless networks and link protocols, mobile networking including support for the Internet Protocol suite, mobile middleware, and mobile applications. Students complete multiple experiments and design projects. **ECE 4574: Large-Scale Software Engineering Systems** Large-scale software implementations of the hierarchy of engineering analysis, design, and decision evaluation. Computer-aided engineering programs with state-of-the-art computer tools and methods. Operator overloading, dynamic polymorphism, graphical user interfaces, generic programming, dynamic link libraries, and multiple threads. **ECE 4605: Radio Engineering** Wireless application circuit design for gain and filter control at radio frequencies to interface the baseband processing systems and the antennas of communication systems. Design of radio transmitter and receiver circuits using scattering-parameter methods. Circuits include oscillators, radio frequency amplifiers and matching networks, mixers and detectors. **ECE 4624: Digital Signal Processing and Filter Design** Analysis, design, and realization of digital filters. Discrete Fourier Transform algorithms, digital filter design procedures, coefficient quantization, finite wordlength arithmetic, fixed point implementation, limit cycles, noise shaping, decimation and interpolation. **ECE 4675: Radio Engineering Lab** Wireless circuit design. Laboratory techniques for radio frequencies. 4675: Design of amplifiers and oscillators.

School Name	Duke University
Data Source	"Electrical Engineering Major" (http://www.ee.duke.edu/undergrads/ee.php) "ECE Courses" (http://www.ee.duke.edu/downloads/ECECourses.pdf)
Classification	Capstone Certified
Program Description	Students must take at least one of the elective design courses listed. There appears to be no course in the curriculum that addresses professional practice or technical writing issues.
Course Descriptions	**ECE 123: Photonic and Electronic Design Projects** A team activity based on photonic and electronic design problems obtained from industry involving the formulation and written presentation of a solution to the design problem; the execution and evaluation of the approved design; and a written and oral presentation of the performance of the design solution all for faculty review. The design project exposes students to basic scientific concepts and to the processes by which scientific and technological advances are made and incorporated into society. **ECE 164L: Electronic Design Projects** Electronics project laboratory in which individuals or small teams, build, and test custom designed circuits or small systems to gain experience in the design process. Requirements: a written plan, project organization, a written report describing the project and test results, a presentation to the class of the constructed project. **ECE 251: Advanced Digital System Design** Theory and hands-on experience in advanced digital system design. High-speed design, high complexity design (more than 10,000 gates), implementation technology selection, system modeling, power and clock distribution, line termination, and cooling. Case studies and demonstrations. Extensive use of CAD tools for logic minimization, logic synthesis, and system simulation. Rapid system prototyping with off-the-shelf and custom components. Laboratory exercises and a semester project. **ECE 261: Full Custom VLSI Design** A first course in VLSI design with CMOS technologies. A study of devices, circuits, fabrication technology, logic

	design techniques, subsystem design and system architecture. Modeling of circuits and subsystems. Testing of gates, subsystems and chips, and design for testability. The fundamentals of full-custom design, and some semi-custom design. **ECE 275: Microwave Electronic Circuits** Microwave circuit analysis and design techniques. Properties of planar transmission lines for integrated circuits. Matrix and computer aided methods for analysis and design of circuit components. Analysis and design of input, output, and interstage networks for microwave transistor amplifiers and oscillators. Topics on stability, noise, and signal distortion.

School Name	University of California – Los Angeles
Data Source	“Undergraduate Program of Study” (http://www.ee.ucla.edu/academics/course_reqs/undergrad.htm)
Classification	Unclassified
Program Description	N/A
Course Descriptions	N/A

School Name	University of California – San Diego
Data Source	"Electrical and Computer Engineering Program" (http://www.ece.ucsd.edu:16080/undergraduate/ general_info/electrical.pdf)
Classification	Capstone Certified
Program Description	Students must take at least one of the elective design courses listed. There appears to be no course in the curriculum that addresses professional practice or technical writing issues.
Course Descriptions	**ECE 111: Advanced Digital Design Project** Advanced topics in digital circuits and systems. Use of computers and design automation tools. Hazard elimination, synchronous/asnychronous FSM synthesis, synchronization and arbitration, pipelining and timing issues. Problem sets and design exercises. A large-scale design project. Simulation and/or rapid prototyping. **ECE 118: Computer Interfacing** Interfacing computers and embedded controllers to the real world: busses, interrupts, DMA, memory mapping, concurrency, digital I/O, standards for serial and parallel communications, A/D, D/A, sensors, signal conditioning, video, and closed loop control. Students design and construct an interfacing project. **ECE 155: Digital Recording Projects** These courses will be concerned with modulation and coding techniques for digital recording channels. In winter and spring quarters, students will perform experiments and/or computer simulations. **ECE 191: Engineering Group Design Project** Groups of students work to design, build, demonstrate, and document an engineering project. All students give weekly progress reports of their tasks and contribute a section to the final project report. **ECE 192: Engineering Design** Students complete a project comprising at least 50 percent or more engineering design to satisfy the following features: student creativity, open-ended formulation of a problem statement/specifications, consideration of alternative solutions/realistic constraints. Written final report required.

	PHYS 121: Experimental Techniques A laboratory-lecture course on the performance of scientific experiments with an emphasis on the use of microcomputers for control and data handling. Topics include microcomputer-architecture, interfacing, and programming, digital to analog and analog to digital conversion, asynchronous buses, interrupt and control techniques, transducers, actuators, digital signal processing–signal filtering, deconvolution, averaging and detection, construction techniques–soldering, parts selection, assembly methods, project management–planning, funding, scheduling, and utilization of personnel.

School Name	University of Maryland – College Park
Data Source	"Degree Requirements" (http://www.ece.umd.edu/Academic/Under/ degree_requirements.html) "Undergraduate Course Descriptions" (http://www.ee.umd.edu/Academic/Under/ucourses1.htm)
Classification	Capstone Certified
Program Description	Students must take ENGL 393 and at least one of the elective design courses listed. There appears to be no course in the curriculum that addresses professional practice issues.
Course Descriptions	**ENGL 393: Technical Writing** This course teaches students to write letters, memos, descriptions, instructions, proposals, technical reports, and resumes. Like all Professional Writing courses, 393 is designed to prepare students for writing they will do in the workplace. **ENEE 408A: Microprocessor-Based Design** Team-based design and implementation of a microprocessor-based system to solve a real-world problem. Development of system specifications, completion of parallel design tasks, software and hardware integration, system testing and documentation. **ENEE 408B: Digital VLSI Design** Utilization of modern CAD tools for the design of medium-complexity digital VLSI chips. The designs are developed by small student teams and include chip layouts and simulation results. Teams are given the option of having their designs fabricated externally and subsequently testing the fabricated chips for additional credit. **ENEE 408C: Modern Digital System Design** A real-world digital system design experience that prepares students for careers in FPGA and ASIC design. Student teams use the Verilog hardware description language together with industry-standard simulation and synthesis tools to design medium-complexity digital chips that are ultimately configured and tested on FPGA's. **ENEE 408D: Mixed Signal VLSI Design** Design of very large scale electronic circuits, including layout, circuit analysis and component selection. Extensive

	use of SPICE and circuit layout CAD tools. Following current industry paradigms, the class emulates a design house, where chips are completely designed and thoroughly simulated prior to their fabrication in a foundry. **ENEE 408E: Optical System Design** Team-based optical system design including overall system layout, analysis, and component selection. Systems designed include sources, passive components and detectors. **ENEE 408F: Communication and Signal Processing System Design** Team-based design and implementation of a communication system or component on a digital signal processor (DSP) platform. **ENEE 408G: Multimedia Signal Processing** An introductory course on multimedia signal processing bringing real-world design experience to students using state-of-the-art multimedia software and hardware. Each week there will be one 75-minute lecture and three-hour design lab (see below). Lectures will provide basic theories and principles on multimedia compression, processing, communications, security, and recognition. **CMSC 435: Software Engineering** State of the art technique in software design and development. Laboratory experience in applying the techniques covered. Structured design, structured programming, top-down design and development, segmentation and modularization techniques, iterative enhancement, design and code inspection techniques, correctness, and chief-programmer teams. The development of a large software project.

School Name	University of Southern California
Data Source	“Undergraduate Handbook” (http://ee.usc.edu/publications/ 2003_undergrad_handbook.pdf) “Course Descriptions” (http://ee.usc.edu/current/descriptions/index.html)
Classification	Capstone Certified
Program Description	Students must take at least one of the elective design courses listed. There appears to be no course in the curriculum that addresses professional practice or technical writing issues.
Course Descriptions	**EE 434L: Digital Signal Processing Design Laboratory** Experiments and design project in digital signal processing (e.g., real-time DSP, acoustics, video) including: systems specification, preliminary analysis, trade-off studies, implementation, presentation. **EE 447: Mixed Signal Electronic Circuits** Application of solid-state devices to the design of linear and mixed-signal systems. Laboratory experiments and projects involving the design of electronic hardware. **EE 459L: Senior Design Project** Design, implementation and test of a computer hardware project, architecture, 1/0 interfaces, application specific hardware: presentation and demonstration. **EE 478L: Digital and Electronic Circuit Design** Design of digital electronic circuits. Laboratory experiments and an extensive term project using digital hardware. **EE 483: Introduction to Digital Signal Processing** Fundamentals of digital signal processing covering: discrete time linear systems, quantization, sampling, Z-transforms, Fourier transforms, FFTs and filter design. **EE 484: Communications System Design** Design and analysis of analog and digital communication systems. System models, requirements development, performance analysis and component selection techniques. Comprehensive system design project.

School Name	University of Washington
Data Source	"Undergraduate Handbook" (http://www.ee.washington.edu/undergrad/handbook/hdbktoc.html) "EE Course Descriptions" (http://www.ee.washington.edu/academic/courses.html)
Classification	Capstone Certified
Program Description	Students must take TC 231, TC 333, and at least one of the elective design courses listed. There appears to be no course in the curriculum that addresses professional practice issues.
Course Descriptions	**TC 231: Introduction to Technical Writing** Principles of organizing, developing, and writing technical information. Report forms and rhetorical patterns common to scientific and technical disciplines. Technical writing conventions such as headings, illustrations, style, and tone. Numerous written assignments required. **TC 333: Advanced Technical Writing and Oral Presentation** Emphasis on the presentation of technical information to various audiences. Style of writing required for proposals, reports, and journal articles. Oral presentation principles, including use of visuals, as well as organizing and presenting an effective talk. **EE 433: Analog Circuit Design** Design of analog circuits and systems applying modern integrated circuit technology: operational amplifiers, differential amplifiers, active filters, voltage references and regulators. **EE 449: Design of Automatic Control Systems** Design problems for aerospace vehicles, systems with unstable dynamics, lightly damped modes, nonminimum phase, nonlinear dynamics. Computer-aided analysis, design, and simulation, with laboratory hardware-in-the-loop testing. Team design reviews, oral presentations. **EE 452: Power Electronics Design** Electronic conversion and control of electrical power. Includes semiconductor switching devices, power converter circuits, design of magnetics, and control of power converters. Also ac/ac, ac/dc, and dc/dc power converters;

	circuit simulation; extensive laboratory work a four-week power converter design project. **EE 456: CAD of Power System** Design-oriented course in power system engineering. Students are assigned a project concerning system operation and planning, steady-state and dynamic behaviors of power systems, or distribution systems. Each involves formulation of design criteria, development of approach, application of existing software. **EE 463: Simulation of Autonomous Systems** Design-oriented course in autonomous mobile robots. C programming, motors, sensors, IR and RF wireless communication, digital image processing, and robot motion control. Laboratory exercises include design, construction, and testing of autonomous mobile robots, which compete at the end of term. **EE 477: VLSI II** Provides a fairly deep understanding of how IC-based memory and datapath blocks are designed using static and dynamic CMOS technologies. Gives students extensive experience with industry-standard computer-aided design tools, including Cadence (Virtuoso, DRC, LVS) and Avanti (Hspice). **EE 478: Design of Computer Subsystems** Design of digital computer subsystems and systems, using SSI, MSI, and LSI digital components. Combinational logic, sequential logic, memory hardware designs, I/O hardware and interface design, system design steps, high-speed digital circuit design, noise reduction techniques, and hardware description language. One four-hour laboratory each week and design project. **EE 481: Microwave Electronic Design** Design of microwave circuits using S-parameter techniques. Measurement techniques, CAD of microwave systems. Includes design, fabrication, and evaluation of a microwave amplifier. **EE 496: Robust Electrical Engineering Design: Integrated Circuit II** Robust engineering design process applied to integrated

	circuit design implemented in a design project selected by student teams, including sensitivity analysis and definition of design specifications. Second course of a two-course sequence. **EE 498: Robust Electrical Engineering Design: Consumer Electronics II** Robust engineering design process applied to consumer electronics design implemented in a design project selected by student teams, including sensitivity analysis and definition of design specifications.

School Name	Rose-Hulman Institute of Technology
Data Source	"Degree Requirements" (http://www.rose-hulman.edu/ece/degree.htm) "ECE Course Descriptions" (http://www.rose-hulman.edu/Catalogue05-06/courses-ece.htm)
Classification	Capstone
Program Description	Students are required to take all of the courses listed in the order they are listed.
Course Descriptions	**RH 330: Technical Communications** Discusses the preparation and presentation of engineering reports, both oral and written. **ECE 361: Engineering Practice** Creativity, project design specifications, team roles, effective conduct of team meetings, written and oral communication skills, ethics and professionalism, completion of team project(s). **ECE 362: Principles of Design** System engineering, team project involving conception, design specifications, conceptual design, scheduling, project management, business plan, market survey, and budgeting that culminates in a written proposal and oral presentation requesting funds for development of a product. **ECE 460: Engineering Design I** The third in a sequence of formal design courses that emphasizes completion of a client-driven project using the design process. Student teams carry a project from inception to completion to satisfy the need of a client. Integral laboratory. **ECE 461: Engineering Design II** Continuation of the design project from ECE 460. Offered over two terms; no credit will be granted for the first term alone. Six credits will be granted after completion of the second term. Integral laboratory.

School Name	Harvey Mudd University
Data Source	“Engineering Advising Handbook” (http://www.eng.hmc.edu/EngWebsite/DeptHbook/05-06AdvisingHandbook.pdf) “Course Information” (http://www.eng.hmc.edu/EngWebsite/index.php?page=CourseDisplay.php)
Classification	Capstone
Program Description	Students are required to take all of the courses listed in the order they are listed. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**E 4: Introduction to Engineering Design** Design problems are, typically, open-ended and ill-structured. Students work in small teams applying techniques for solving design problems that are, normally, posed by not-for-profit clients. The project work is enhanced with lectures and reading on design theory and methods, project management techniques, and engineering ethics. Enrollment limited to first-year students and sophomores, or by permission of the instructor. **E 8: Design Representation and Realization** A practicum that provides hands-on, shop-based experience to give meaning to the concepts of design representation and design realization. Students are introduced to ASME drawing specifications and are required to generate drawings that meet the appropriate specifications. Students manufacture a tool tray, screwdriver, and hammer, using equipment in the student shop. Students are exposed to limits in the design and manufacture of engineering components. Open to all students. **E 80: Experimental Engineering** A laboratory course designed to acquaint the student with the basic techniques of instrumentation and measurement in both the laboratory and in engineering field measurements. Emphasis on experimental problem solving in real systems. **E 111 – 113: Engineering Clinic** Pioneered by the Department of Engineering at Harvey Mudd College in 1965, the Engineering Clinic brings together teams of students to work with faculty advisors on carefully selected, industry- and government-sponsored design and development projects. The students plan and

	execute their projects; the projects are their own work. The faculty advise, coach, monitor, evaluate, and provide feedback. The student teams also coordinate their activities with sponsors’ liaisons to ensure that the sponsors’ goals are achieved and that the design experience corresponds as closely as possible to what engineers encounter in actual practice. Thus, the questions and problems that student teams face are typical of those regularly confronted by practicing engineers, and the solutions they devise must work in practice, not just in theory. We believe that our broad engineering program will produce engineers capable of adapting changing technologies to expanding human needs, while at the same time being sensitive to the impact of their work on society, both within the United States and globally.

School Name	Cooper Union
Data Source	"BE curricula" (http://www.ee.cooper.edu/becurricula.php) "Undergraduate Course Descriptions" (http://www.ee.cooper.edu/coursedescriptions.php#Undergraduate)
Classification	Capstone
Program Description	Students are required to take all of the courses listed in the order they are listed. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**ECE 193: Electrical & Computer Engineering Projects I** An introduction to laboratory techniques for electrical and computer engineering. Electronic test equipment including: DVM, oscilloscope, curve tracer, spectrum analyzer. Circuit analysis and design, discrete and integrated electronic components and circuits. Several experiments of limited scope provide an understanding of the fundamental building blocked employed in the more advanced designs in successive projects courses. Students give weekly oral presentations and demonstrate laboratory proficiency through in-class demonstrations and concise, formal technical reports. **ECE 194: Electrical & Computer Engineering Projects II** Principles learned in ECE193 are applied to the design, construction and characterization of electrical and computer engineering projects of significant complexity. Assignments typically involve both analog and digital design, and students are free to pursue any solution that satisfies the engineering requirements and meets with the instructor's approval. Formal and informal lectures are given on safety, circuit operation and design, and construction techniques; participation in design reviews and technical reports. **ECE 195: Electrical & Computer Engineering Projects III** ECE195 and ECE196 constitute the year-long senior design project. Students work in small groups on projects chosen with the advice and consent of the faculty advisor. Projects may be oriented towards research or product development, and may be in any area of electrical and computer engineering, such as in: computer engineering, signal

	processing (imaging, sensor arrays, multimedia), telecommunications, computer networks, microwaves, optics, advanced electronics, VLSI chip design, or an interdisciplinary area such as robotics or bioengineering. Students perform all aspects of project management, such as scheduling, budgeting, system design and developing milestones, as well as technical work including hardware and software implementation, testing and performance evaluation. Students also give several spontaneous and rehearsed oral presentations and prepare written reports. Students attend weekly lectures covering: social, economic, legal and ethical issues; safety and laboratory practice; design methodologies; technical writing; preparation of multimedia presentations and tailoring presentations to target audiences. **ECE 196: Electrical & Computer Engineering Projects IV** Culmination of senior design projects.

School Name	California Polytechnic State University – San Luis Obispo
Data Source	"BSEE Degree Requirements" (http://www.calpoly.edu/~acadprog/2003depts/cengr/ee_dept/ee.html) "BSCPE Degree Requirements" (http://www.eadvise.calpoly.edu/policy/forms/cpe_curclm0507.pdf) "EE Courses" (http://www.calpoly.edu/~acadprog/2003depts/cengr/ee_dept/eecrs2003.html) "CPE Courses" (http://www.calpoly.edu/~acadprog/2003depts/cengr/cpe_prog/cpecrs2003.html)
Classification	Capstone
Program Description	Students must take ENGL 149 and all of the courses listed in the order they are listed. (EE students take the EE courses and CPE students take the CPE courses)
Course Descriptions	**ENGL 149: Technical Writing for Engineers** The principles of technical writing. Discussion and application of rhetorical principles in technical environments. Study of methods, resources and common formats used in corporate or research writing. 4 lectures. **EE 460: Senior Project Preparation** Methods for project planning including Gantt Chart, critical paths, time and cost estimates. Experience in subsystem definition. Case studies and examples. Ethical code of conduct in the engineering profession. Definition and planning of senior project. **EE 461/2: Senior Project** Selection and completion of a project under faculty supervision. Projects typical of problems which graduates must solve in their fields of employment. Project results are presented in a formal report. Minimum 150 hours total time. **EE 463/4: Senior Project Design Laboratory** Selection and completion of a project under faculty supervision. Projects typical of problems which graduates must solve in their fields of employment. Project results are presented in a formal report. EE 463: 3 laboratories. EE 464: 2 laboratories.

	CPE 350: CPE Capstone Preparation Definition and specification of a system to be constructed in CPE 450; requirements elicitation techniques, research and data gathering methods; project planning, time and budget estimating; project team organization. Ethics and professionalism. **CPE 450: CPE Capstone Project** Team-based design, construction and deployment of an embedded system that includes a custom-built computer. Technical management of product development teams. Technical documentation, configuration management, quality assurance, integration and systems testing. Professionalism. 3 lectures, 1 laboratory. **CPE 461/2: Senior Project** Selection and completion of an individual or team project in laboratory environment. Project results are presented in a formal report. CPE 461: 3 laboratories. CPE 462: 2 laboratories.

School Name	United States Military Academy
Data Source	"Program Details" (http://www.eecs.usma.edu/yellow_book/class2006/ ee.pdf#nameddest=ah)
Classification	Captsone
Program Description	Students are required to take all of the courses listed in the order they are listed. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**EE 401: Electronic System Design I** This course is part of a two-semester team design experience in electrical engineering that integrates math, science, and engineering into a comprehensive system. The system design encompasses both analog and digital electronics, and may also include sub-systems. Projects are open-ended and must result in a product that performs within pre-determined or negotiated constraints. The system design problem draws from a variety of science and engineering experiences within the curriculum and requires significant cadet creativity and decision-making. Acceptable solutions must address technological, social, political, economic, and ethical considerations. Classroom instruction addresses design methodologies and common system components. Course requirements include periodic in-progress reviews, written and oral reports. **EE 402: Electronic System Design II** This course provides a team design experience in electrical engineering that integrates math, science, and engineering into a comprehensive system. The system design encompasses both analog and digital electronics, and may also include sub-systems. Projects are open-ended and must result in a product that performs within pre-determined or negotiated constraints. The system design problem draws from a variety of science and engineering experiences within the curriculum and requires significant cadet creativity and decision-making. Course requirements include periodic in-progress reviews, written and oral reports, and completion of the iterative design, build, and test cycle for a functional system. Factors such as feasibility, reliability, and economics must be assessed.

School Name	United States Naval Academy
Data Source	"EE Courses" (http://www.usna.edu/AcDean/courses/ee.html)
Classification	Capstone
Program Description	Students are required to take both of the design courses listed. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**EE 411: Electrical Engineering Design I** A series of design problems are presented to take the student through the total design process from specification to verification of performance. In addition to technical design, factors such as safety, economics, and ethical and societal implications are considered. A small project is executed and evaluated. Each student chooses a project and develops and submits a proposed design to be completed in EE414. The proposal is presented to the student's peers and project advisors in lieu of a final exam. **EE 414: Electrical Engineering Design II** This course provides practice in engineering design, development, and prototype testing. Following approval of the project by the instructor, the student develops a prototype, troubleshoots, and gathers performance data, and completes construction and packaging of the final design. A formal briefing to peers and EE Department faculty follows a written final project report on the completed project in lieu of a final exam.

School Name	United States Air Force Academy
Data Source	"FAQs on the Electrical Engineering Field" (http://atlas.usafa.af.mil/dfee/FAQs/EE_major.htm)
Classification	Capstone
Program Description	Students are required to take all of the courses listed. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**EE 463: Design Project Techniques** Applications of integrated circuits and discrete components in electronic subsystems. Design and analysis of circuits with emphasis on design approach, construction, measurement, evaluation and reporting of results. Lab. **EE 464: Design Project** This capstone laboratory course integrates advanced concepts in electronics, instrumentation, signal processing, communications, control theory, and microcomputer hardware with production and management methods developed in ENGR 410 (Engineering Systems Design). The course uses a design project to emphasize Air Force applications and requires cadets to design, build, and test the project, and present a report on their work. Lab. Project. Final report.

School Name	Bucknell University
Data Source	“Degree Requirements” (http://www.bucknell.edu/Academics/Course_Catalog/The_Curricula/Engineering_Curricula.html#bsee) “Course Descriptions” (http://www.bucknell.edu/Academics/Course_Catalog/Course_Descriptions/Electrical_Engineering.html)
Classification	Capstone
Program Description	Students are required to take all of the courses listed in the order they are listed. There appears to be no course in the curriculum that addresses professional practice issues.
Course Descriptions	**ENGR 138: Written and Oral Communication** Written and oral forms of communication, including preparation and presentation of job/internship search communication, memos, letters, and reports, with consideration of audience, purpose, structure, style, and language. Prerequisite: 100-level English course. **ELEC 400: Project Planning and Engineering Design** Introduction to design, conceptual design, design evaluation, project planning and scheduling for Electrical Engineering Senior Design Project and development of design proposal. **ELEC 420: Electrical Engineering Design** This project-oriented course serves as a Capstone course for electrical engineering majors. The student is expected to develop, implement, and demonstrate a solution to a problem. The problem will be selected by the student in collaboration with the instructor. The student’s contribution to the solution will be evaluated based on a written and an oral report. Students are expected to participate in local student paper contests.

School Name	Kettering University
Data Source	“Curriculum Announcement” (http://www.collegesource.org/displayinfo/catalink.asp?pid={A8D3CDD1-DC53-4E1E-BF20-E01936E14307}&oig={7EA47252-3AFB-4745-A8DD-A0E7F22D9E2F}&vt=5)
Classification	Capstone
Program Description	Students must take COMM 101, COMM 301, and the design project course corresponding to their degree option.
Course Descriptions	**COMM 101: Written & Oral Communication I** This course is designed to help students write and speak effectively in academic settings and in their work organizations. Basic principles underlying practical communication techniques are taught, with an emphasis on skills for conveying technical and business information. Students engage in writing and speaking assignments that familiarize them with appropriate formats for those kinds of communication. Student performance is analyzed as a means of promoting individual improvement. **COMM 301: Written & Oral Communication II** The course prepares students to launch their thesis project and to perform other advanced writing and speaking tasks. Thus students will employ the concepts and skills gained in the foundational course Written & Oral Communication I (COMM101). Emphasis is placed on helping students to communicate effectively in regard to the technologies and business purposes of their own workplace and profession. Students’ development of the required skills is demonstrated in writing assignments and oral presentations. Credit must be received for the course before a student’s Senior Thesis Assignment Proposal will be processed for its approval. **EE 490: Senior Electrical Engineering Design Project** Students will design, implement, document, and present a device or system as a significant capstone project. The project will emphasize electrical engineering, but will be multidisciplinary. **CE 490: Senior Computer Engineering Design Project** Students are prepared for engineering practice through a major design experience based on knowledge and skills acquired in earlier course work. They work in teams to

	design and develop a prototype embedded-computer or other complex digital system to meet a given specification. The specification requires the design to incorporate relevant engineering standards and to address most of the following: manufacturability, sustainability, and economic, environmental, ethical, health and safety, social, and political considerations. Designs are documented in a professional manner and presented publicly.

School Name	Embry Riddle Aeronautical University – Florida
Data Source	"Degree Requirements" (http://www.erau.edu/pr/degrees/b-electric_engineering.html#req) "Undergraduate Catalog" (http://www.erau.edu/er/catalogs/elements0506/UGCatalogWeb.pdf)
Classification	Capstone
Program Description	Students are required to take COM 221 and one of the following sequences: electrical engineers take EE 420, EE 428, and EE 421 while computer engineers take SE 300, CEC 420, EE 428, and CEC 421.
Course Descriptions	**COM 221: Technical Report Writing** Preparation of formal and informal technical reports, abstracts, resumes, and business correspondence. Major emphasis placed on the long technical paper and the acquisition of advanced writing skills. **EE 420: Avionics Preliminary Design** Study of FAA requirements governing design of airborne electronic equipment. Study of component and subsystem specification and design practices. Application of the above in the preparation of a proposal/design plan for an airborne electrical/electronic subsystem. Integrate the knowledge gained throughout the curriculum with practical aspects of the practice of engineering to enable the student to comprehend engineering as a pivotal aspect of the business cycle and to responsibly participate in society by the practice of his/her profession. The course will introduce the combination of hardware and software requirements and preliminary design, preparation of project, and testing plans following established industry standards. **EE 428: Preliminary Design II** Study of component and system testing. Preparation of senior design proposal. **EE 421: Senior Capstone Project** Continuation of EE 420 or EE 428. Senior-level project. Students will work as members of a team in the execution of winning proposals from EE 420/428. The course incorporates the combination of hardware and software detailed design, implementation, and testing following established industry standards.

	CEC 420: Computer Systems Design I This course introduces students to discussing issues of management, planning, task assignment, resource allocation, requirement collection, and system specification and design. The team working in a distributed environment will develop a base for implementation of a computer-centered system with elements of both hardware and software. **CEC 421: Computer Systems Design II** This course continues with project development, focusing on issues of detailed design, modularization, component selection, coding, assembling, and testing. The team working in a distributed environment will implement and test a computer-centered system with elements of both hardware and software. **SE 300: Software Engineering Practices** This course introduces students to the fundamental principles and methodologies of large-scale software development. Students learn about the theory and practice of software engineering and work as part of a team on a full life-cycle software project that includes planning, software specification, software design, coding, inspections, and testing. The course has a closed laboratory that includes activities that guide project teams through a software development process and support team project activities such as team building, planning, requirements analysis and specification, design, testing, and the use of tools.

School Name	Milwaukee School of Engineering
Data Source	"Electrical Engineering Track Curriculum" (http://www.msoe.edu/eecs/cese/courses/curriculum.php?progcode=EE15.1&abet=0) "Computer Engineering Track Curriculum" (http://www.msoe.edu/eecs/cese/courses/curriculum.php?progcode=CE)
Classification	Capstone
Program Description	Students are required to take EN 132 and one of the following sequences: electrical engineers take EE 407, EE 408, and EE 409 while computer engineers take CS 400, CS 401, and CS 489.
Course Descriptions	**EN 132: Technical Composition** The purpose of this course is to acquaint students with the principles of effective, audience-centered technical communication and provide them with practice in writing letters, memoranda, proposals, and an informal and a formal report. The course also requires students to become familiar with accepted research techniques and to apply them in a written formal report and in an oral presentation. Students also learn the principles of graphical design and the importance of visual representation in technical communication, both oral and written, and students are expected to incorporate appropriate graphics into their written and oral communication. Finally, students are taught how to organize and present technical material orally in an effective manner. **EE 407: Senior Design Project I** This is the first course in the three-course EE senior design sequence. Students form three- or four-person design teams and define a design problem which has alternative solutions. These alternatives are analyzed and evaluated to determine the most feasible solution(s). A formal feasibility study is required of each team, culminating in a written report and an oral presentation. Topics discussed in class include conceptual thinking and problem definition, ideation techniques, feasibility studies, technical specifications, design aids and research techniques, prototype development and testing, and verbal and written communications. Each student is required to keep a design log in a bound engineering notebook. **EE 408: Senior Design Project II**

	This is a continuation of the EE design project defined by each design team in EE-407. The most feasible solution is now explored in-depth and design options are detailed starting with block diagrams and progressing to detailed schematics. Each team's goal should be to have a detailed paper design complete by the end of the course, and to have ordered any parts which may have unusually long lead times. A formal design report and presentation is required. The two-hour lecture is used to discuss design techniques, and to have guest lecturers on practical design considerations such as manufacturability, testability, and packaging. **EE 409: Senior Design Project III** This is a continuation of the EE design project defined by each design team in EE-407 and designed in EE-408. The design is now built, tested, modified, retested and completely documented in this final course of the senior design sequence. It is expected that each team will have a working prototype to demonstrate by the end of this course. The two-hour lecture is used to discuss problems, and to have guest lecturers on practical design considerations such as compliance to standards, noise testing, legal considerations, safety and cost. **CS 400: Senior Design Project I** This is the first course in the senior design sequence in which each student team works on a design project from conception through implementation and testing. The team first explores technology issues related to the project and then prepares a complete design. Teams meet regularly with the instructor to track technical and project management issues. Written reports and oral presentations are required. **CS 401: Senior Design Project II** This is the second course in the senior design sequence. In this course, the student team implements the design developed in CS-400. Teams meet regularly with the instructor to track technical and project management issues. Complete project documentation, written reports and oral presentations are required. **CS 489: Software Engineering Design** Software development techniques are studied, with an emphasis on the life cycle issues of requirements analysis,

	specifications, design, implementation, testing, maintenance and documentation of complex software systems. Computer-aided software engineering (CASE) tools are used to support the development process, which is build around the objected-oriented (OO) paradigm. Students participate in a team project to design, implement and test a complete software system.

School Name	Villanova University
Data Source	"Electrical Engineering Curriculum" (http://www.engineering.villanova.edu/academics/ece/undergraduate_students/ee/curriculum.htm) "Computer Engineering Curriculum" (http://www.engineering.villanova.edu/academics/ece/undergraduate_students/cpe/curriculum.htm) "Course Catalog" (https://novasis.villanova.edu/pls/bannerprd/bvckctlg.P_DisplayCourses?cat_term_in=200620&subj_code_in=ECE&crse_strt_in=&crse_end_in=&call_proc_in=bvckctlg.P_DisplaySubjects*cat_term_in=200620)
Classification	Capstone
Program Description	Students are required to take one of the following sequences: electrical engineers take ECE 3970, EE 4970, and EE 4972 while computer engineers take ECE 3971, ECE 4971, ECE 4973, and CSC 4700. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**ECE 3970: Design Seminar – EE** Areas and career paths in electrical engineering. Overview of required senior project courses and faculty project sponsors. Engineering design, project selection requirements, technical communications, information gathering. Requires selection of design project adviser, project topic, and a formal written project proposal. **ECE 3971: Design Seminar – CPE** Areas and career paths in computer engineering. Overview of required senior project courses and faculty project sponsors. Engineering design, project selection requirements, technical communications, information gathering. Requires selection of design project adviser, project topic, and a formal written project proposal. **ECE 4970: Design Project – EE** Completion of the design project presented in ECE 3970. Requirements: written and oral progress reports, demonstration of achieved objectives, formal written final report, oral presentation. Design groups meet weekly with their instructors.

	ECE 4971: Design Project – CPE Completion of the design project presented in ECE 3971. Written and oral progress reports, demonstration of achieved objectives, formal written final report, oral presentation. Design groups meet weekly with their instructors. **ECE 4972: Design Project Report – EE** Preparation and presentation of a final written report and a formal presentation of each project team's senior design project completed in ECE 4970. **ECE 4973: Design Project Report – CPE** Preparation and presentation of a final written report and a formal presentation of each project team's senior design project completed in ECE 4971. **CSC 4700: Software Engineering** Management and production of software systems; the software life cycle; software design techniques and methodologies; participation in a team software development project.

School Name	California State Polytechnic University – Pamona
Data Source	"Electrical Engineering Curriculum" (http://www.csupomona.edu/~ece/program/electric.html) "University Catalog" (http://www.csupomona.edu/~academic/catalog/col_schol/ index.htm)
Classification	Capstone
Program Description	Students must take ECE 464, EGR 481, EGR 482, one of the writing/communication courses (ECE 311, ENG 105, or PHL 202), and one of the senior design courses (ECE 463 or ECE 465).
Course Descriptions	**ECE 311: Engineering Reports, Specifications & Proposals** Techniques of conveying and interpreting technical information, developing a facility with engineering language, both written and oral, reading drawings, making sketches and reading schematics, technical proposals. Avoiding technical, legal and manufacturing pitfalls in engineering specification. **ENG 105: Freshman English II** Frequent papers, chiefly informative and persuasive, with an emphasis on language and logic. Techniques of the research paper. Readings. 4 lectures/problem-solving. **PHL 202: Critical Thinking** Inductive and deductive processes in reasoning; the effects of semantic considerations on reasoning and communication, with examples from contemporary society. Emphasis on detection and avoidance of logical and semantic errors. 4 lectures/problem-solving. **EGR 481/2: Project Design & Applications** Selection and completion of scientific/technological synthesis application project under faculty supervision. Multidisciplinary team project. Projects which graduates solve in discipline of practice. Both formal written and oral reports. Minimum time commitment: 120 hours. **ECE 464: Professional Topics for Engineers** The course consists of developments, policies, practices, procedures and ethics in the areas of Electrical and Computer Engineering. 1 hour lecture and problem solving sessions. Prerequisites: ENG 104 or equivalent, GWT, all

	100 and 200 level courses. All but 12 units of the 300-level courses. 50 units or less to graduate. ECE 465/466/467 Senior Design Team project (1,2,2, units, respectively) Active participation in and significant contribution to a department approved senior level team project under faculty supervision. Results are presented in a formal format, including a report, presentation to faculty and demonstration of hardware. Minimum expected time per student: 150 hours. **ECE 465: Senior Design Team Project** Completion of a capstone senior design team project under faculty supervision. Project results are presented in a formal report. Minimum 120 hours required. **ECE 463: Undergraduate Seminar** New developments, policies, practices, procedures and ethics in electrical and computer engineering. Each student is responsible for the preparation of an approved project proposal in the field of electrical and computer engineering. 2 lectures/problem-solving.

School Name	Lafayette College
Data Source	"University Catalog" (http://www.lafayette.edu/academics/catalog/catalog_2005_07.pdf)
Classification	Capstone
Program Description	Students must take both of the design courses listed below. There appears to be no course in the curriculum that addresses professional practice or technical writing issues.
Course Descriptions	**ECE 491: Senior Project** This course uses a data network to introduce students to team project work. Course topics include computer networks from the physical layer to communication protocols. A representative network is designed and realized in the laboratory. Students work in teams; different teams design sub-systems of the network. Lecture/laboratory. **ECE 492: Electrical Engineering Design Laboratory II** In this course individual or team design projects are completed. The course includes both laboratory and library work. Initial proposals, progress reports, and final design documents are required. Projects can cover the entire spectrum of activities within electrical engineering. Laboratory.

School Name	Loyola Marymount University
Data Source	"Undergraduate Bulletin" (http://registrar.lmu.edu/Bulletins/2004-05_Bulletin.pdf)
Classification	Capstone
Program Description	Students must take all of the courses listed. There appears to be no course that addresses professional practice or technical writing issues.
Course Descriptions	**ELEC 400: Design Methodology** A study of design methodology and development of professional project-oriented skills including communication, team management, creative problem solving, interpersonal management, and leadership skills. Case studies are used to describe the application of project-oriented skills to the solution of design problems. **ELEC 401: Senior Lab I** Course is intended to provide a laboratory experience related to other senior level courses; emphasis is on design and technical report writing and oral presentation. **ELEC 402: Senior Project** A study of design methodology and development of professional project-oriented skills including communication, team management, creative problem solving, interpersonal management, and leadership skills. Team project activities are used to apply project-oriented skills to solution of design problems. Periodic design reports and design reviews are presented to and critiqued by the faculty and the design team.

School Name	San Jose State University
Data Source	"Requirements for B.S.E.E. Degree" (http://www.engr.sjsu.edu/electrical/bsee_requirement.htm) "SJSU Catalog" (http://info.sjsu.edu/web-dbgen/catalog/)
Classification	Capstone
Program Description	Students must take ENGR 100W and one of the following sequences: electrical engineers take EE 198A and EE 198B while computer engineers take CMPE 131, CMPE 195A, and CMPE 195B.
Course Descriptions	**ENGR 100W: Engineering Reports** Regular technical writing assignments and company-focused oral presentations while integrating effects of environmental factors as they relate to products, systems and engineering processes. **EE 198A: Senior Design Project I** Individual or group design project proposal and initial design in approved E.E. area; oral and written reports; professional seminar. **EE 198B: Senior Design Project II** Implementation of individual or group design projects initiated in EE 198A. Oral and written reports. **CMPE 131: Software Engineering I** Why software engineering? What is software engineering? Software development lifecycle activities: project planning and management requirements analysis, requirement specification. Software design, software testing, verification, validation, and documentation. Software quality assurance and review techniques, software maintenance, team-based projects. **CMPE 195A: Senior Computer Engineering Design Project I** Individual or group design projects. Proposal preparation with plans and specifications; oral and written reports; professional seminars. **CMPE 195B: Senior Computer Engineering Design Project II** Constructions, testing, and evaluation of the design from 195A culminating in demonstrations and written and oral

	presentations to faculty and peers.

School Name	Santa Clara University
Data Source	"Undergraduate Bulletin" (http://www.scu.edu/bulletin/undergraduate/)
Classification	Capstone
Program Description	Students must take all courses listed in the order they are listed. There appears to be no course in the curriculum that addresses professional practice issues.
Course Descriptions	**ENGL 182: Introduction to Technical Writing for Engineers** The basics of effective written technical communication, including problem analysis, audience analysis, document design, revision, and the design and use of graphics. Satisfies the third writing requirement for engineering majors. Open only to junior and senior engineering majors. **ELEN 194: Design Project I** Specification of an engineering project, selected with the mutual agreement of the student and the project advisor. Complete initial design with sufficient detail to estimate the effectiveness of the project. Initial draft of the project report. **ELEN 195: Design Project II** Continued design and construction of the project, system, or device. Second draft of project report. **ELEN 196: Design Project III** Continued design and construction of the project, system, or device. Final report.

School Name	United States Coast Guard Academy
Data Source	“Electrical Engineering – Computer Track” (http://www.cga.edu/academics/academicmajors/electricalcourseinforcomputertrack.htm) “Electrical Engineering – Systems Track” (http://www.cga.edu/academics/academicmajors/electricalcourseinforsystemstrack.htm)
Classification	Capstone
Program Description	Students are required to take 1426 and 1436. Students on the Computer Track are additionally required to take 1362 and 1458. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**1426: Projects in Electrical/Computer Engineering I** This is the first of two capstone Electrical and Computer Engineering courses offered in the senior year. Classroom topics focus on filling a toolbox of skills and concepts for succeeding as a Coast Guard engineering project manager. Some of these are the tradeoffs between cost, requirements and schedule; the engineering design process; engineering ethics and economics; and the unwritten laws of engineering. In the lab, cadets begin a two-semester major engineering design project. Working as an apprentice engineer alongside faculty member(s) and contractors as part of a small Coast Guard project team, students are presented with real-world engineering problems that require formal resolution with no predetermined outcome. A typical project includes requirements definition, computer programming, computer algorithm design and system implementation, data gathering and analysis, and presentation of results in a paper and oral presentation. Field trips to Coast Guard labs are included, as are project related trips to various locations in the U.S. **1436: Projects in Electrical/Computer Engineering II** This second senior-year capstone course completes the cadet's electrical and computer engineering program of instruction. Cadets bring their two-semester major engineering project to a close, and present the results to Academy faculty and to professionals from Coast Guard Headquarters and various Coast Guard engineering commands. Classroom topics typically center on one or more contemporary electrical and computer engineering topics such as radionavigation, electrical machines, computer networks, etc. Field trips to Coast Guard labs are

	included, as are project-related trips to various locations in the U.S. **1362: Software Design I** This course reinforces procedural programming skills and introduces object-oriented programming. It emphasizes procedural and object-oriented software design. Other topics include software test design, abstract data types, data structures (arrays and lists) and common algorithms (searching and sorting). Lab work emphasizes a planned approach to software testing and debugging. Students design and implement a number of practical programs, culminating in a major software design project that is performed in groups. **1458: Software Design II** This course continues the study of software design. Major topics include data structures (lists, stacks, queues, hash tables, trees, and graphs) and accompanying algorithms, and common methods for algorithm design (greedy, backtracking, and divide-and conquer). Focus is on using standard data structures and algorithms in the design of software to solve specific problems. Lab work emphasizes a planned approach to software design, testing and debugging. Students design and implement a number of practical programs, culminating in a major software design project that is performed in groups.

School Name	Baylor University
Data Source	"B.S. Degree Requirements" (http://www.ecs.baylor.edu/engineering/undergraduate/index.php?id=29391)
Classification	Capstone
Program Description	Students are required to take all courses listed in the order they are listed.
Course Descriptions	**ENGL 3300: Technical and Professional Writing** Study of the presentation of technical materials and professional reports. Emphasis on student practice of these skills. **EGR 3305: Social and Ethical Issues in Engineering** Study of the relationship between engineering, technology, and society. Topics include philosophical perspectives on engineering and technology, technological values, impact of technological change, social and ethical responsibilities of engineers, and public technology policy. Christian responses to these issues will be explored. **EGR 3380: Engineering Design I** Introduction to the engineering design process via team-based projects encompassing the design, construction and testing of an engineering device or system. Projects will emphasize oral, written, and graphical engineering communication skills and topics related to engineering professionalism. **EGR 4390: Engineering Design II** A capstone design course for emphasizing the decision-making process that must be used by a practicing engineer to apply the basic sciences in order to convert resources optimally to meet stated objectives. Oral and written reports are required.

School Name	Gonzaga University
Data Source	"B.S. in Electrical Engineering" (http://barney.gonzaga.edu/~ece/eecurriculum.html) "B.S. in Computer Engineering" (http://barney.gonzaga.edu/~ece/cpecurriculum.html)
Classification	Capstone
Program Description	Students are required to take all courses listed in the order they are listed. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**EENG 491: Senior Design Project I (Lecture)** Students learn what constitutes an engineering project, and how to work in a project team; project requirements and specifications; effective interaction with a client; literature search; conceptual design and project plan; oral and written technical presentations; detailed design and implementation techniques; project management: tasks, schedules, budget, critical items and fall back options; ethics and professionalism. **EENG 491L: Senior Design Project I (Project Work)** Students work as a team to produce a project proposal. The proposal must describe the project requirements, conceptual design, management plan and project cost. **EENG 492: Senior Design Project II** Implementation, management, and completion of the project proposed in EENG 491; use of resources within and outside of the team to accomplish the project objectives; project documentation; demonstration of compliance with requirements; presentation of results and submission of comprehensive written report.

School Name	Union College
Data Source	"Electrical and Computer Engineering Course Listing" (http://www.union.edu/Academics/Departments/ deptView.php?mode=catalog&year=2005&code=EE)
Classification	Capstone
Program Description	Students are required to take all the courses listed below. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**ECE 497-499: Electrical and Computer Engineering Capstone Design Project** Two course equivalent. Students begin this sequence of courses in the spring of their junior year. The spring term includes a seminar component. In the fall and winter terms, students complete the design, implementation, and evaluation of a system under the supervision of one or more faculty members. Topics in the seminar include professional and ethical responsibilities; the historical and societal context of electrical and computer engineering; contemporary issues, and the specification, analysis, design, implementation, and testing phases of a design project. Research papers, project reports, and oral presentations are required

School Name	University of Colorado – Colorado Springs
Data Source	"Degree Requirements – EE" (http://ece.eas.uccs.edu/BSEE.html) "Degree Requirements – CmpE" (http://ece.eas.uccs.edu/BSCpE.html)
Classification	Capstone
Program Description	Students are required to take ENGL 309, ECE 4890, and ECE 4899. Computer engineers must additionally take CS 330.
Course Descriptions	**ENGL 309: Technical Writing and Presentation** This course is designed to teach students how to present technical information effectively both through written reports and through oral presentations. It is taught in an electronic classroom with access to software tools for the design of both written and oral presentations. **CS 330: Software Engineering** Software engineering methodologies. The software lifecycle. Emphasis on the design, development and implementation of a software system. A course project provides the student teams practical application of the software engineering techniques. **ECE 4890: Senior Seminar** Design principles and a variety of realistic constraints such as economic factors, safety, reliability, aesthetics, ethics, and social impact; design project organization and design goals; techniques for making oral presentations and organizing written reports; interviewing and resume writing skills along with the art of making a favorable first impression. **ECE 4899: Design Project** A project lab taken during the last semester of the senior year for the design of system components and systems in the areas of communications, computer engineering, controls, digital signal processing, electromagnetics, microelectronic fabrication processes, or CMOS integrated circuits. Students will identify, select, and complete a design project. Design specification, analysis, design, simulation and/or construction of a successful project is required for completion of the course.

School Name	University of Michigan – Dearborn
Data Source	"Undergraduate Curriculum – EE" (http://www.engin.umd.umich.edu/ECE/newECE/programs/Curr-EE-Fall-2005.pdf) "Undergraduate Curriculum – CE" (http://www.engin.umd.umich.edu/ECE/newECE/programs/Curr-COEN-Fall2005.pdf)
Classification	Capstone
Program Description	Students are required to take COMP 270 and the design project course corresponding to their degree option.
Course Descriptions	**COMP 270: Technical Writing for Engineers** Instruction and practice in designing technical reports. Students study the rhetorical problems facing professional engineers and learn practical strategies for analyzing and communicating technical information to technical and non-technical audiences. This course fulfills the Composition II requirement for engineering majors, who must achieve second semester sophomore standing before taking the course. **ECE 4985: Electrical Engineering Design** The course is conducted as a guided project design course over a two-semester period, with the class divided into teams, each assigned a specific design project. Periodic progress reports, a final written report, an oral presentation and project demonstration are required. Cost analysis, societal impact, safety issues, evaluation of design alternatives and application of engineering principles will be emphasized. A series of lectures on design issues will be presented during the first semester. **ECE 4986: Computer Engineering Design** The course is conducted as a guided project design course over a two-semester period, with the class divided into teams, each assigned a specific design project. Periodic progress reports, a final written report, an oral presentation and project demonstration are required. Cost analysis, societal impact, safety issues, evaluation of design alternatives and application of engineering principles will be emphasized. A series of lectures on design issues will be presented during the first semester.

School Name	Valparaiso University
Data Source	"Electrical Engineering Plan of Study" (http://www.valpo.edu/engineering/electrical/elec04.php) "Computer Engineering Plan of Study" (http://www.valpo.edu/engineering/electrical/comp04.php)
Classification	Capstone
Program Description	Students are required to take all the courses listed in the order they are listed. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**GE 301: Principles of Engineering Practice** A discussion of engineering practice including topics such as engineering economics, management, professional ethics, and safety. Student will participate on multidisciplinary teams. **GE 497: Senior Design Project I** The application of theoretical and experimental engineering concepts in the analysis and design of an engineering system. Students form teams to plan and organize a multidisciplinary project. **GE 498: Senior Design Project II** A continuation of GE 497. Projects are built, tested, reported and documented.

School Name	Virginia Military Institute
Data Source	“Synopsis of Electrical Engineering Curriculum” (http://www.vmi.edu/media/CM_publications/ synop%20Electrical%20Engineering.pdf) “Course Catalog” (http://www.vmi.edu/media/cm_publications/ cat%20Courses.pdf)
Classification	Capstone
Program Description	Students are required to take all courses listed in the order they are listed. There appears to be no course in the curriculum that addresses technical writing issues.
Course Descriptions	**EE 321: Systems Design I** EE 321 gives an overview of project management to include aspects of team building, systems engineering, engineering economics, design, testing, safety, legal and ethical implications. The systems engineering process is described in terms of: 1) Requirements Analysis, 2) Functional Analysis and Allocation, 3) Design Synthesis, and 4) Design and Test and Evaluation Feedback loops of the process. Project life cycles are discussed in terms of four phases: 1) concept exploration, 2) system development and demonstration, 3) system production and deployment, and 4) system sustainment. A Work Breakdown Structure is used to organize and identify the product and process components of a project that is realized in the second semester of this course. **EE 422: Systems Design II** EE 422 provides an introduction to and overview of the elements and methodology of Engineering System Design. A specific engineering system design problem is assigned to the class, which is subdivided into teams. The teams, working independently, apply a system engineering approach to the design problem giving consideration to realistic constraints including technological, economic, social-political, environmental, ethical, legal, and safety. The teams will identify the different aspects of the overall system design and assign individual team members responsibilities for components, subsystems or other specific aspects of the design. The team will integrate the contributions of the individual team members into a coherent design that provides an acceptable solution to the systems design problem while at the same time demonstrating an understanding of the application of

	engineering systems design methodology. Each team will present their design in a detailed written and oral presentation at the end of the semester.